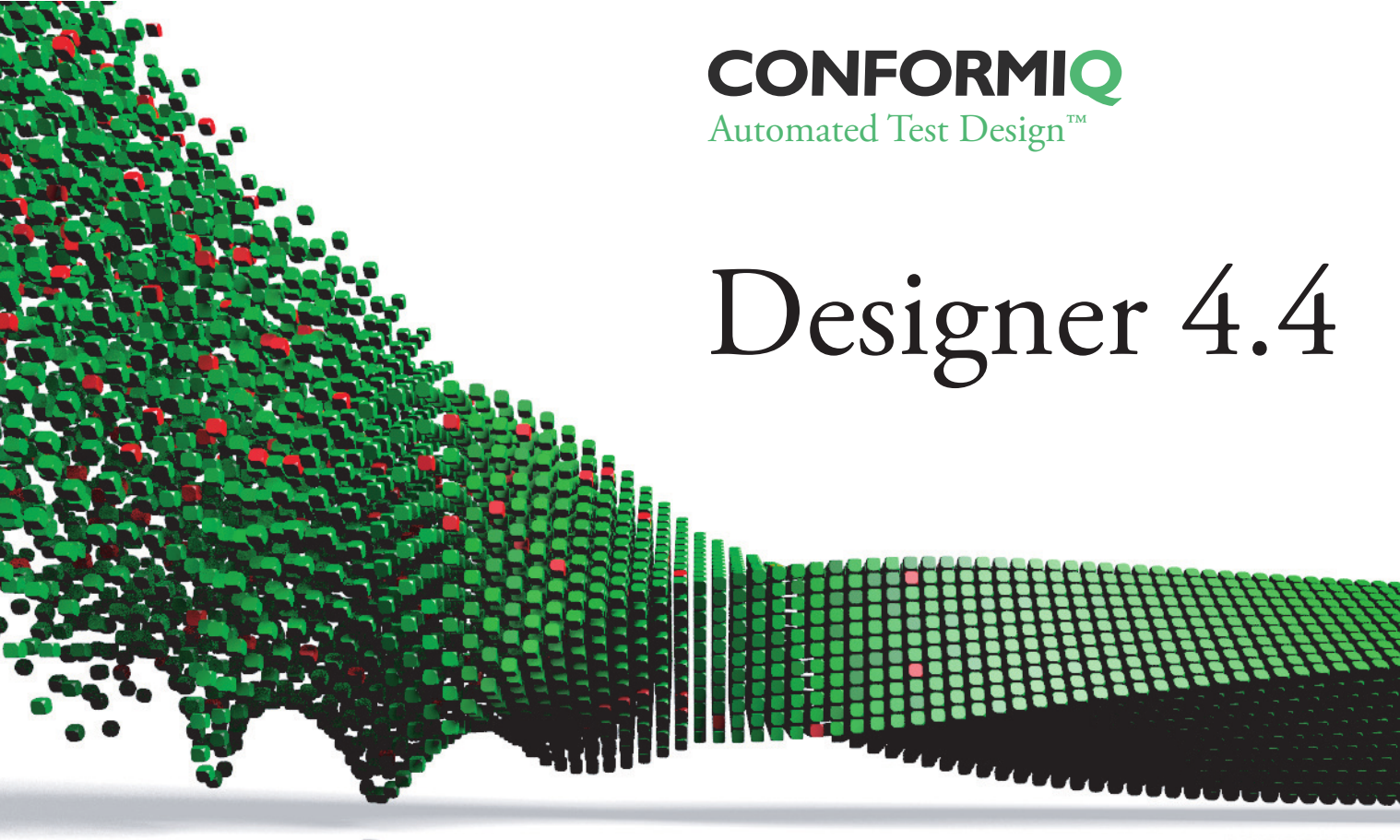


CONFORMIQ

Automated Test Design™

Designer 4.4

User Manual

Copyright © Conformiq Inc. and its subsidiaries 2011. All Rights Reserved. Unauthorized reproduction prohibited. Conformiq and Conformiq Designer are trademarks of Conformiq Inc. and its subsidiaries. Some other trademarks belong to their respective owners.

Conformiq User Manual

Copyright (C) Conformiq Software Oy and its subsidiaries 1998-2011. All Rights Reserved. All information may be subject to change without notice.

For more information about Conformiq Software and its products, please go to http://www.conformiq.com/.

Conformiq, Conformiq Designer and Conformiq Modeler are trademarks of Conformiq Software Oy. Java is a trademark of Sun Microsystems. UML is a trademark of the Object Management Group. Other trademarks appearing in the text belong to their respective owners.

Table of Contents

1 Introduction 12
1.1 The Design-Validation Cycle 13
1.2 Costs of Testing 14
1.3 Conformiq in Software Process 16
1.4 Benefits of Conformiq 17

2 Installing Conformiq 19
2.1 System Requirements 20
2.1.1 Conformiq Eclipse Client Requirements 20
2.1.2 Conformiq Computation Server Requirements 21
2.1.3 Other Requirements 21
2.2 Preparations 22
2.3 Notes on Migrating to 4.3 Release 22
2.4 Installing Conformiq on Windows 23
2.4.1 How to Install Conformiq on Windows 23
2.4.2 How to Uninstall Conformiq on Windows 26
2.5 Installing Conformiq on Linux 26
2.5.1 How to Install Conformiq on Linux 26
2.5.2 How to Uninstall Conformiq on Linux 28
2.6 Checking the QEC Installation 29
2.7 License Management in Conformiq 31
2.7.1 Configuring Conformiq Feature Set 32
2.7.2 Conformiq Evaluation 33
2.7.3 Named User Licensing 34
2.7.4 Floating Licensing 35
2.7.5 Obtaining Node Identifiers 38
2.8 License Server Management 38
2.8.1 Flexera based license server 39
2.8.2 Web-based license server 39

3 Testing with Conformiq 42
3.1 Quick Start of Using Conformiq 43
3.2 Deploying Example Conformiq Projects 44
3.3 How to Switch to Conformiq Perspective 47
3.4 How to Configure Conformiq Eclipse Client 47
3.5 How to Work with Conformiq Projects 50
3.6 How to Select Models 54
3.7 How to Create Test Design Configurations 57
3.8 How to Create Use Cases 58
3.8.1 Why Create a Use Case 59
3.8.2 Basic Features of a Use Case 61
3.8.3 Defining a Use Case 63
3.8.4 Updating a Use Case 65
3.9 How to Configure Test Generation 66
3.9.1 How to Configure Global Testing Parameters 66
3.9.2 How to Configure Design Configuration Specific Testing Parameters 72
3.10 How to Generate Tests 79
3.10.1 Test Case Selection in Conformiq 80
3.10.2 Perturbation 82
3.10.3 Test Generation Time Warnings 85
3.10.4 Model Profiler 88
3.10.5 Intelligent Test Case Naming 91
3.11 How to Analyze Test Generation Results 94
3.11.1 Coverage Editor 96
3.11.2 Test Case List 97
3.11.3 Traceability Matrix View 99
3.11.4 Test Dependency Matrix 100
3.11.5 Test Case View 102
3.11.6 Test Step View 104
3.11.7 Model Browser 105
3.11.8 Execution Trace View 108

3.11.9 Analyzing Model Defects 109
3.12 How to Export Test Cases 124
3.12.1 How to Use Scripters from Scripter Warehouse 128
3.12.2 How to Use Script Backends Shipped with Conformiq 131
3.13 Test Case Management 148
3.14 Managing Conformiq Projects 151
3.15 Command Line User Interface 152

4 Creating Models in QML 157
4.1 Textual Notation of QML 158
4.2 Basic Language Features 159
4.2.1 Keywords 160
4.2.2 Comments 164
4.2.3 Literals 164
4.2.4 Operators 165
4.2.5 Data Types 167
4.2.6 Access Modifiers 183
4.2.7 Type Aliases 183
4.2.8 Control structures 184
4.2.9 Input and Output 186
4.2.10 System Block 188
4.2.11 Main Entry Point 189
4.2.12 Globals and Functions 189
4.2.13 Modifiers 190
4.3 Object Orientation 190
4.3.1 Inheritance 190
4.3.2 Interfaces 191
4.3.3 Operator Overloading 191
4.3.4 Templates 192
4.3.5 Nullable Types 194
4.3.6 Implicitly Typed Local Variables 195

4.4 Modeling for Test Generation 197
4.4.1 Modeling Combinatorial Test Data 197
4.4.2 Model Regions 199
4.4.3 Regions with No Coverage Goals 201
4.4.4 Scenario and Narrative 202
4.5 Predefined Data Types 203
4.5.1 Class and Record Super Types 203
4.5.2 Threads and Communication 203
4.5.3 Exceptions 206
4.5.4 Synchronization 207
4.5.5 Containers 208
4.6 Predefined Functions 212
4.6.1 Assertion Like Functions 213
4.6.2 Query Functions for Fields of Structured Types 214
4.6.3 Requirements 215
4.6.4 Mathematical Functions 216
4.6.5 Probabilities and Priorities 217
4.6.6 End Conditions for Test Generation 219
4.6.7 Miscellaneous Functions 221
4.7 Graphical Notation of QML 222
4.7.1 State Machines 222
4.7.2 Transition Strings 224
4.7.3 Internal Transitions of a State 227
4.7.4 Entry and Exit Actions 228
4.7.5 Including State Charts 229
4.8 Examples 231
4.8.1 A Simple Echo Model 231
4.8.2 Another Echo Model 231
4.8.3 Yet Another Echo Model 233
4.9 Importing TTCN-3 Type Definitions Into Conformiq 235
4.9.1 Introduction 235

4.9.2 How to Include TTCN Files in a Conformiq Project 236
4.9.3 Basic types 237
4.9.4 Record, Set and Union Types 242
4.9.5 List Types 243
4.9.6 Enumerated Types 243
4.9.7 Aliasing 244
4.9.8 Constants 244
4.9.9 Special types 245
4.9.10 Summary of TTCN-3 limitations 245

5 Using Conformiq Modeler 246
5.1 Opening a model 248
5.2 Saving a model 249
5.3 State machines 249
5.4 Drawing 249
5.4.1 Zooming 250
5.4.2 Scrolling 250
5.4.3 States 250
5.4.4 Transitions 251
5.4.5 Notes and note connectors 251
5.5 Undo and Redo 252

6 Importing Models from Third Party Tools 253
6.1 Enterprise Architect 254
6.1.1 Imported Components 255
6.1.2 Project Layout 255
6.1.3 Declaring State Machines 256
6.1.4 Defining Transitions 256
6.1.5 States 257
6.1.6 QML Tagged Comments 259
6.1.7 System Block 259

6.1.8 Main Entry Point 260
6.1.9 Records 260
6.1.10 Exporting from Enterprise Architect 262
6.1.11 Importing into Conformiq 262
6.1.12 Components not Imported 263
6.2 Rhapsody System Designer 263
6.2.1 Imported Components 263
6.2.2 Example Echo Model 265
6.2.3 Example Echo Model in Rhapsody 268
6.2.4 Summary 275
6.3 Rational Software Architect 275

7 Test and Requirement Management Tool Integrations 285
7.1 Configuring a Test / Requirement Management Tool Integration 287
7.2 HP Quality Center Integration 289
7.2.1 Annotating the Model with Requirements 291
7.2.2 Configuring the HP Quality Center Connection 292
7.3 IBM Rational RequisitePro Integration 294
7.3.1 Annotating the Model with Requirements 294
7.3.2 Configuring the IBM Rational RequisitePro Connection 295
7.4 IBM Rational DOORS Integration 295
7.4.1 Annotating the Model with Requirements 296
7.4.2 Configuring the IBM Rational DOORS Connection 297

8 Creating Conformiq Scripting Backends 299
8.1 Communicating Using QML Datum Interface 300
8.2 Creating Scripting Backends in Java 301
8.3 Exposing Scripting Backend Configuration 312
8.4 Preparing Eclipse Workbench 315
8.5 Creating Java Project for Scripting Backends 315
8.6 Creating Scripting Backend JAR 317

8.7 Debugging Scripting Backends 318

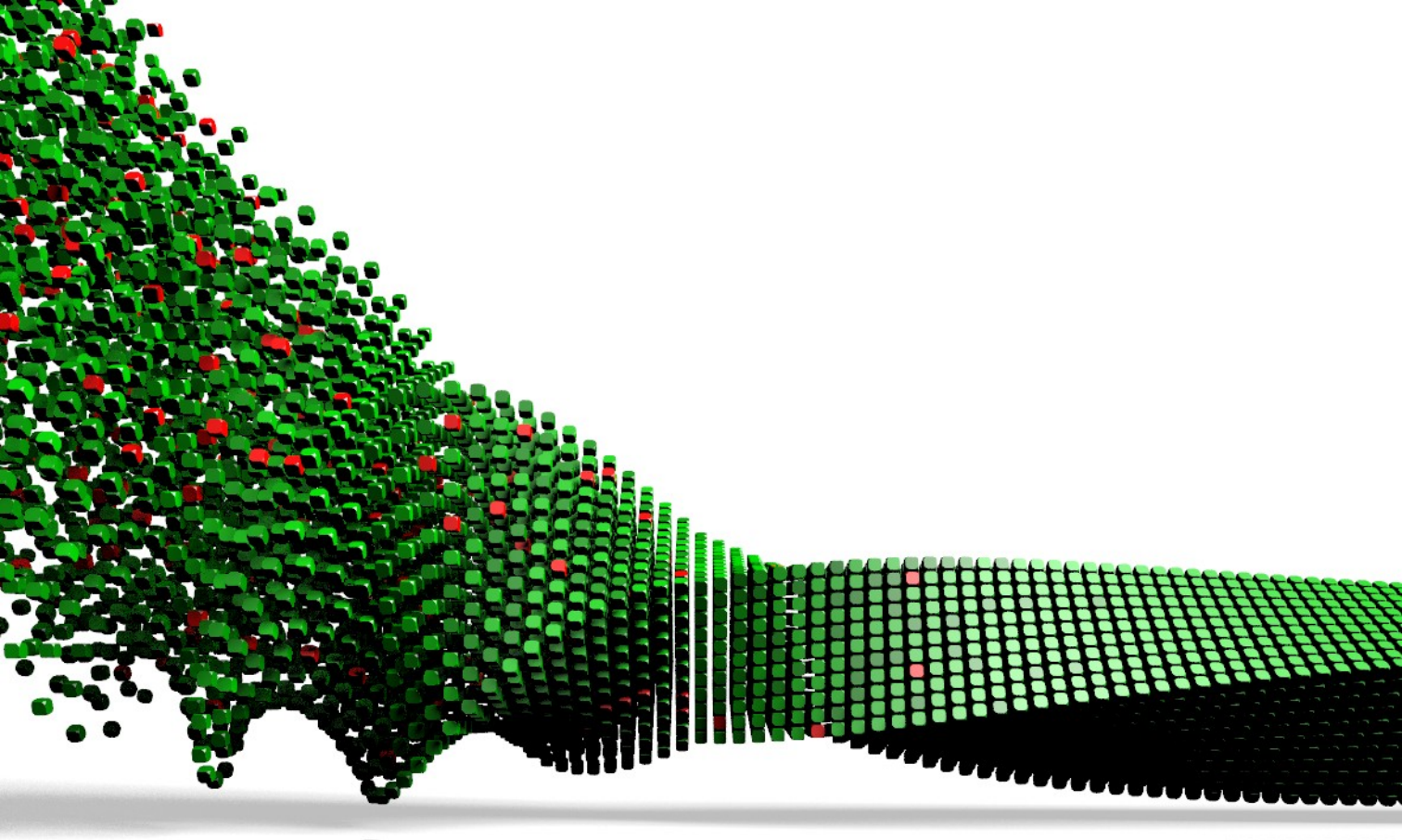
9 Support and Troubleshooting 319
9.1 Troubleshooting Guidelines 320
9.1.1 Troubleshooting QEC 320
9.1.2 Performance Problems 322
9.2 Reporting Problems with Conformiq 323

A Conformiq Release Notes 325
A.1 Download and Install 326
A.2 Conformiq 4.4.2 327
A.2.1 What's New or Changed 327
A.3 Conformiq 4.4.1 331
A.3.1 What's New or Changed 331
A.4 Conformiq 4.4.0 334
A.4.1 Use Case Support 335
A.4.2 Perturbation (Generation of Non Standard Data Distribution) 335
A.4.3 Intelligent Test Case Naming 336
A.4.4 Improved Detection of Parsing Errors 336
A.4.5 Command Line Interface for Batch Mode Execution 336
A.4.6 Other New Features 336
A.4.7 Other Updates 337
A.4.8 Known Problems 338
A.5 Conformiq 4.3.1 341
A.6 Conformiq 4.3.0 342
A.6.1 Model Debugger 342
A.6.2 Support for Flexera Publisher Based Licenses 342
A.6.3 Internal Database Migration from PostgreSQL to SQLite 343
A.6.4 Support for Temporarily Increasing the Search Depth 343
A.6.5 Support for Including State Charts 343
A.6.6 Experimental Support for Model Regions 344

A.7 Conformiq 4.2.2 344
A.8 Conformiq 4.2.1 345
A.9 Conformiq 4.2.0 346
A.10 Qtronic 2.1.2 349
A.11 Qtronic 2.1.1 349
A.12 Qtronic 2.1.0 350
A.13 Qtronic 2.0.3 353
A.14 Qtronic 2.0.2 353
A.15 Qtronic 2.0.1 354
A.16 Qtronic 2.0.0 354

B Plugin API Reference Manual 357
com.conformiq.qtronic2.QMLValue Interface 358
com.conformiq.qtronic2.QMLTypeVisitor Interface 358
com.conformiq.qtronic2.Checkpoint Interface 360
com.conformiq.qtronic2.QMLRecordType Interface 360
com.conformiq.qtronic2.QMLNumber Interface 361
com.conformiq.qtronic2.Plugin Class 363
com.conformiq.qtronic2.QMLOptional Interface 364
com.conformiq.qtronic2.TimeStamp Class 365
com.conformiq.qtronic2.Checkpoint.CheckpointStatus Class 366
com.conformiq.qtronic2.QMLArrayType Interface 367
com.conformiq.qtronic2.QMLUnion Interface 368
com.conformiq.qtronic2.QMLRecord Interface 368
com.conformiq.qtronic2.QMLBoolean Interface 370
com.conformiq.qtronic2.QMLRecordTypeField Interface 370
com.conformiq.qtronic2.MetaDataDictionary Interface 371
com.conformiq.qtronic2.QMLType Interface 373
com.conformiq.qtronic2.Checkpoint.CheckpointType Class 374
com.conformiq.qtronic2.QMLStringType Interface 375
com.conformiq.qtronic2.QMLRecordField Interface 375

com.conformiq.qtronic2.QMLUnionType Interface 376
com.conformiq.qtronic2.QMLBooleanType Interface 376
com.conformiq.qtronic2.QMLValueVisitor Interface 377
com.conformiq.qtronic2.QMLNumberType Interface 378
com.conformiq.qtronic2.QMLOptionalType Interface 379
com.conformiq.qtronic2.ScriptBackend Class 380
com.conformiq.qtronic2.QMLArray Interface 384
com.conformiq.qtronic2.SynchronousPlugin Class 384
com.conformiq.qtronic2.QMLString Interface 386
com.conformiq.qtronic2.NotificationSink Interface 386



I Introduction

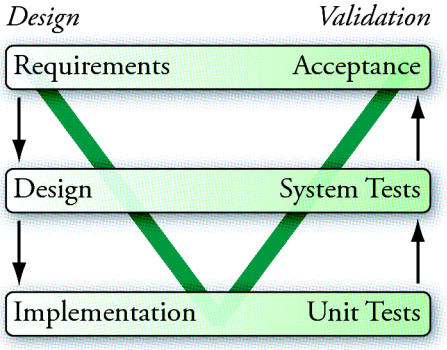
Welcome to Conformiq, the world's leading solution for automatic model driven test case design!

Conformiq technology is the result of more than six years of continuous programming and development. It is based on advanced discrete mathematics and theory of computer science, yet it is a very pragmatic tool. The benefits that Conformiq brings to day-to-day software development are tangible and pervasive. It reduces risks caused by unintentionally missing tests or defective tests and increases test design productivity and target system quality.

In this introduction we go through the value proposition for Conformiq: what it is, why it exists, and how it can help you.

1.1 The Design-Validation Cycle

On high level, software development can be seen to consist of interleaved cycles of *design* and *validation*. Design is about creating business requirements and architectural plans, writing running code, producing implementations. Validation is about checking what has already been designed with respect to other explicit artifacts as well as implicit requirements of the process.



Overview of the traditional V model

For example, in the traditional "V model" there is first a design phase, a process beginning with the business requirements and ending with implementation. This is followed by a validation phase which begins with unit testing and progresses until post-deployment monitoring. In more recent process models, such as those under the umbrella of "agile processes", design and validation are further intertwined. Still, design and validation are always two fundamental parts of the process. The underlying reason lies in the psychology of the person: the human brain has a tendency to make mistakes, and hence everything created must be cross-checked to ensure its quality. This is true also within the realm of software engineering. The design-validation cycle is a fundamental characteristic of all software processes.

Some of the best known methods for *validation* include testing, inspections and reviews, and static analysis. **Conformiq Designer** is a tool for optimizing test design as well as the whole design-validation cycle at large. However, it is not a tool for source code reviewing or static analysis.

1.2 Costs of Testing

Software testing is a broad domain of concepts and processes. Today it is probably the most important way to validate software. Testing consumes significant amounts of time and money, estimated between 30 to 90 percentage of total development budgets.

The division of testing costs is dependent upon how testing is organized. Typical ways to organize testing include:

- Manual testing
- Record and replay
- Development and execution of custom testing software

Manual testing means that a testing engineer or tester interacts with the system under test personally, often following a plan written down in a human tongue, creating reports of his or her experiences with the system as well as of any defects spotted. The dominating costs are personnel costs caused directly by the testing activity on an hour to hour basis.

Record and replay is a widely deployed paradigm for testing software with graphical user interfaces. First, a tester interacts manually with the system under test through the user interface. The interaction is recorded in a suitable way. Later the interaction can be replayed repeatedly and the workings of the system compared to the expected, "golden" outcomes that come either from the original execution or from an otherwise prepared data table. In record and replay the costs are attributed to the initial production of the scripts, the maintenance and modification of them later when the product or its requirements change during the life cycle, the examination of those cases where tests fail for diagnosis, and the total cost of ownership of the record and replay tool itself.

Record and replay excels in a process where progressive versions of the same software must be tested many times (regression testing). Record and replay achieves relative economics of scale over manual testing when the number of regression test runs grows.

The same is true for using *custom testing software*. This is a typical way to organize regression tests for small units, but it is used also for larger systems. In this approach, a testing engineer creates and maintains custom software whose raison d'être is to, when executed, test some other software. The initial development costs for custom testing software can be higher than for record and replay — at least a different skill set is required — but in the long run it can be more efficient. Typically, a custom testing program can generate millions of different test inputs to a system, and can analyze the outcome from the system in a much more detailed way than a usual record and replay solution.

Because testing is eventually cross-checking an implementation against requirements, all forms of testing create costs related to understanding and analyzing requirements. In the context of manual testing these costs show up as working time spent by testers during the testing activity itself. For custom testing software, both test design as well as analysis of flagged defects incur costs (all automatically spotted defects must be analyzed because it could be that the testing software itself, being just another computer program written by a human, could be incorrect).

For our purposes, a coarse but sufficient way to categorize the cost drivers of a testing process is:

1. Understanding and analyzing requirements
2. Creating and maintaining test artifacts (recorded interactions, custom testing software)
3. Executing tests (either manually or by running automation tools)
4. Analyzing test results
5. Reporting

1.3 Conformiq in Software Process

Conformiq Designer is a tool for automatic test case design that is driven by "design models". This means that Conformiq Designer designs tests for a system automatically when it is given a "design model" of the system as an input. The tests are "black box tests", meaning that they evaluate the system under test based only on its external behavior, not on monitoring its internal workings directly (this kind of testing is called "white box testing").

This "design model" is a description of the intended behavior of the system on some level of abstraction. It is also correct to see it as a golden reference implementation of the system, albeit usually an abstracted and simplified one. This design model can be expressed as a collection of:

1. Textual source files in Java-compatible but extended notation that describe data types, constants, classes and their methods (the extensions include support for value-type records, true static polymorphism, etc.).
2. Statechart diagrams with methods and procedures in Java syntax representing the behavioral logic of active classes, i.e. classes whose instances can "execute on their own" as an alternative to representing the logic textually.
3. Class diagrams as a graphical alternative to declare classes and their relationships.

Design models can also be seen as operational requirements or behavioral requirements. They describe the intended external operational characteristics of the system, in essence how the

system should work from the perspective of a user. Design models do not need to reflect the real implementation structurally as long as they describe the intended outwardly observable characteristics.

Conformiq Designer selects and optionally executes tests automatically based on the design model, and calculates expected answers from the system under test automatically. With Conformiq Designer, there is no need to create test scripts manually or to record them. Test design, optional execution and analysis are all automatic. These benefits directly reduce costs and risks. But behind this level of "obvious" benefits, Conformiq Designer brings in a pervasive change to the software process: it links design with validation in a revolutionary way.

Without Conformiq Designer, testing involves manual translation of requirements into tests and test verdicts. This task is carried out either by a manual tester, a test designer, or an engineer writing testing software — in the last case the costs are the most directly visible. Basically, a custom testing program is just a new expression of the requirements for the system, this time in the form of an executable that checks that the system the executable is run against fulfills the requirements in some, selected cases ("test cases"). This results in having to maintain two artifacts simultaneously: the requirements and the testing software.

This source of costs and risks can be eliminated with the use of Conformiq Designer because the tool generates tests directly from the requirements themselves (when they are expressed as functional models). This results in double benefits: test artifacts do not need to be maintained, and the quality of the requirement documents increases dramatically. After all the tests generated by Conformiq Designer from a design model pass, there is strong evidence that the system and the requirements are mutually coherent. This increases the value of the behavioral requirements as technical documentation for the system.

1.4 Benefits of Conformiq

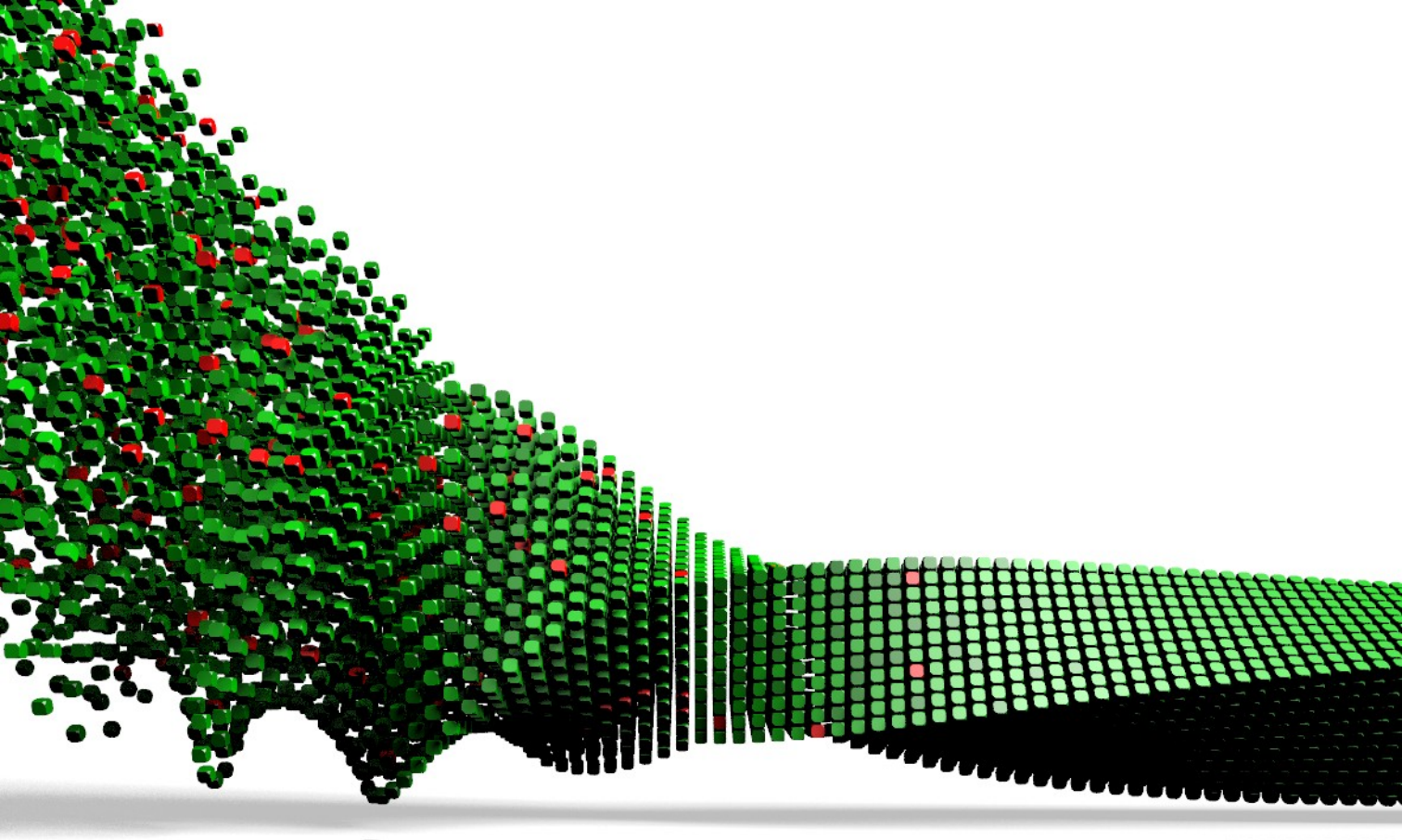
The main benefit of using Conformiq is an increased product quality that is achieved by using the design model as the golden reference implementation of the system. Unlike other testing tools, tests can be automatically generated from the design model.

Conformiq Designer generates a multitude of distinct test cases from the given design model that can be independently executed afterward. Generated test scripts can be stored in a version control system allowing tests to be sent to colleagues or to execute them independently. Automatic test case generation from system models reduces risks and costs: It eliminates the risk of defective test cases and reduces costs by cutting the amount of manual test case maintenance work. One of the most obvious benefits of using Conformiq Designer is that automatic testing based on design models saves effort as there is no need to maintain separate tests and requirement designs. Test execution and analysis are automatic so continuous involvement from engineers is not required.

Since Conformiq Designer creates test cases by analyzing the design model, it is able to infer test cases that could be otherwise overlooked. It also reduces the risk of defective tests as the tests are inferred directly from the design models. For special and important tests, test engineers can write separate use case tests describing certain specific behavior that has to be explicitly tested. Using design models as artifacts for testing has a positive impact on the quality of design models as the model works as documentation for the system also. Whenever an error is found between the model and the implementation both of them are updated. This implies that the system documentation is always up to date and conforms to the system.

Because the design model has such an important role, Conformiq Designer has to offer *model debugging and analysis* features — While the design model is being constructed, Conformiq Designer can be used to determine that there are no execution paths that would lead to internal computation errors, such as division by zero. If Conformiq Designer finds such an instance, it provides a counter-example with the corresponding execution trace and data values enabling the user to correct the model. This automatic model validation feature of Conformiq Designer is reliable and speeds development.

Thorough reports provide all the required information. In addition, Conformiq Designer provides the means to generate custom reports.



2 Installing Conformiq

Conformiq is a professional software tool that installs on supported platforms. However, if you should experience problems with installation of the software after following the guidelines in this chapter, please contact your supplier for advice.

2.1 System Requirements

Conformiq Designer employs client-server architecture where the client user interface is implemented as an Eclipse plugin. The server component — Conformiq Computation Server — can be installed on the same computer as the Conformiq Eclipse Client or on another node on the local area network.

2.1.1 Conformiq Eclipse Client Requirements

Conformiq Eclipse Client is provided as

1. a standalone software as a rich client application that contains a minimal set of plug-ins collectively known as Rich Client Platform (RCP)
2. an Eclipse plugin that requires an existing Eclipse installation.

Conformiq RCP application and Conformiq Eclipse Client plugin versions are provided in two distinct installers.

If Conformiq Eclipse Client is installed as an Eclipse plugin, the required Eclipse must be *Eclipse 3.4 (Ganymede)* or newer. The recommended package is *Eclipse Classic*.

Shared requirements for both of the Conformiq Eclipse Client installation types are enumerated below:

- The required Java environment for running Conformiq Eclipse Client (QEC) is Sun Java 6 or higher.
- The system on which Conformiq Eclipse Client is installed should have at least 4096 MB memory or more, especially if you are taking advantage of Conformiq

Model Debugger, your models are complex, there are great number of test cases, etc.

- A relatively powerful **x86 family processor**, a multiprocessor or multi-core processor computer is recommended.

To run 32-bit version of Conformiq Eclipse Client RCP application version on a 64-bit platform, one must have a 32-bit version of Java Virtual Machine (JVM). The same applies to running 32-bit version of Eclipse on 64-bit platform.

2.1.2 Conformiq Computation Server Requirements

- Windows XP, Windows Vista, Windows 7, and most modern Linux distributions are supported by the Conformiq Computation Server (QCS). It is highly recommended to install SP3 or newer to Windows XP in order to take advantage of the parallel test generation algorithm.
- The system on which Conformiq Computation Server is installed must have at least 4096 MB of memory but 8192 MB or more is recommended.
- We highly recommend a powerful and modern computer with multiprocessor or multi-core **x86 family processor** due to the large amount of calculations the software must do during automatic test generation. The bare minimum for number of cores is 2, but we strongly recommend a configuration with 8 or more cores.

2.1.3 Other Requirements

In addition, these software requirements are needed for a Linux installation:

- The GNU C Library (**libc** that defines "system calls" and other basic functionality) must be 2.4 or newer.

Test generation is a computationally very intensive task and therefore it is recommended to run Conformiq Eclipse Client and Conformiq Computation Server on distinct computers. However, if QEC and QCS are both run on the same computer, the bare minimum amount of physical memory is 4096 MB but it is strongly recommended to have 8192 MB of memory or more and a very powerful multiprocessor or multi-core processor with at least 4 cores.

Linux distribution is provided as a 32 bit installation which can be executed also in 64 bit environments. In order to deploy on 64 bit environment, **ia32-libs** package needs to be installed.

2.2 Preparations

Before starting the actual installation, make sure that the system meets the requirements described in Section System Requirements.

Preparations for Installing Conformiq Eclipse Client

When installing Conformiq Eclipse Client as an Eclipse plugin, make sure that you have a working Eclipse installation in your system. The Eclipse version must be 3.4 (GANYMEDE) or newer. Also make sure that you have the necessary permissions to write Conformiq Eclipse Client plugin information to the Eclipse installation directory.

2.3 Notes on Migrating to 4.3 Release

As of Conformiq 4.2 the server-side database system (PostgreSQL) is replaced with an embedded client-side database system (SQLite). SQLite is designed to be embedded into the software, and it keeps the database in single file, or, if required, even in memory. The Conformiq projects, created with Conformiq 4.2 or newer, cannot be opened with an earlier

version of Conformiq Qtronic.

The PostgreSQL database system has been completely omitted from the Conformiq Tool Suite release as of Conformiq 4.3 meaning that **projects created with Conformiq Qtronic 2.1 or older cannot be opened with Conformiq 4.3 or newer**. However, the PostgreSQL database system is still part of Conformiq 4.2 for the sake of migrating Conformiq projects to the new database system. Therefore in order to migrate a project created with Conformiq Qtronic 2.1 or older, install Conformiq 4.2 on your machine and open the old Conformiq project. The Conformiq 4.2 release will upgrade the project format so that it can be then opened in Conformiq 4.3.

2.4 Installing Conformiq on Windows

Conformiq can be installed on Windows Vista/XP/2000. The software is provided as a 32-bit compilation. It can also be used on 64-bit machines the same as any 32-bit application.

2.4.1 How to Install Conformiq on Windows

Conformiq for Windows is provided as a NullSoft installer.

The installer can be used to install the Conformiq Eclipse Client (QEC) or Conformiq Computation Server (QCS) or both. As mentioned in the Section System Requirements, Conformiq Eclipse Client can be installed as a standalone application (RCP application) or as an Eclipse plugin that requires an existing Eclipse installation. These two are provided in distinct installer packages. Both of the installers will also allow the installation of **Conformiq Modeler**, a light-weight modeling tool for drawing UML state machine diagrams, example models, and more.

The following list details the process of installing Conformiq to your computer:

1. Double-click on the 'Conformiq <version>.exe' installer file in Windows Explorer. This will start the installer.
2. Select the destination folder for the installation. The default is **C:\Program**

Files\Conformiq\Designer. If the installation directory does not exist, the installer will create one.

3. Choose the installed components. There are four different installation groups:

1 **Full**: select all of the components (the default)

2 **Server**: select server components, namely Conformiq Computation Server

3 **Client**: select client components, namely Conformiq Eclipse Client, Conformiq Modeler, and example models

4 **Custom**: lets the user select only those components that are needed

4. If Conformiq Eclipse Client was selected and you are installing it as an Eclipse plugin, the next thing is to specify the directory where Eclipse has been installed.

5. In order to provide a smooth user experience of Conformiq Eclipse Client client, the installer will recommend a few different memory configurations for the Eclipse based client (These configurations are used by the Java Virtual Machine that is responsible of executing the Eclipse. For more information about tuning Java Virtual Machine please refer *Memory Management in the Java HotSpot Virtual Machine* document available online). Select the one that suits your needs the best. If you do not wish to deploy the memory configuration recommended, you can continue without making changes to the configuration. The installer will not recommend this memory configuration if Conformiq Eclipse Client is not selected for installation.

6. Specify file associations, i.e. whether Conformiq Modeler is associated with *.xmi* file extension.

7. Specify the menu items, i.e., whether the installer should create Start Menu items and Desktop shortcuts.

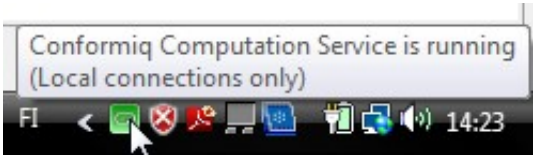
8. Conformiq Computation Server initiates a number of services when launched which require that proper firewall exceptions are added for the various Conformiq Computation Server components in order for it to function properly. Windows

installer can automatically add such firewall exceptions during installation time so that running the Conformiq Computation Server for the first time will not lead Windows firewall to pop up multiple notifications about services demanding access thru firewall. This option is set by default, but can be disabled by deselecting *Add Exceptions to Firewall*.

9. Click **Install**. This will install the selected set of components to your computer.

The Conformiq Computation Server can be started by double clicking the "Conformiq Computation Server" icon in desktop (or directly executing *conformiq-manager.exe* in the installation directory). Once started, QCS will minimize itself to the Windows system tray that you can see on the lower right hand side of the Windows desktop.

As of Conformiq Qtronic 2.1.0, the Conformiq Computation Server is automatically started when the user starts Conformiq Eclipse Client and attempts to establish a connection to Conformiq Computation Server. See the Section How to Configure Conformiq Eclipse Client for more information on how to change this default behavior.



QCS minimized to Windows system tray

As of Conformiq Qtronic 2.1.0, the Conformiq Computation Server has support for distributing the calculation over multiple CPU's. This feature is always enabled in the installed version and therefore does not need to be activated by the user.

2.4.2 How to Uninstall Conformiq on Windows

Conformiq for Windows can be removed from your computer by using the built in feature of Windows for uninstalling programs. In order to uninstall Conformiq, choose Conformiq from the list of installed programs found from *Add or Remove Programs* from *Control Panel* of Windows.

2.5 Installing Conformiq on Linux

Conformiq can be installed on most modern Linux distributions with Intel 586 (Pentium) compatible processors. For support for other processors, please contact your supplier.

2.5.1 How to Install Conformiq on Linux

Conformiq Linux installer is provided as a **bash** script.

The installer can be used to install the Conformiq Eclipse Client or Conformiq Computation Server or both. As mentioned in the Section System Requirements, Conformiq Eclipse Client can be installed as a standalone application (RCP application) or as an Eclipse plugin that requires an existing Eclipse installation. These two are provided in distinct installer packages. Both of the installers will also allow the installation of **Conformiq Modeler**, a light-weight modeling tool for drawing UML state machine diagrams, example models, and more.

Unpack the installer package before continuing with the installation:

- Unpack the installer file using the `tar` command

```
tar xvfz conformiq-<version>-linux-libc-2.4.tgz
```

- Change to the installation directory

```
cd conformiq-<version>-linux-libc-2.4
```

- Execute the **install.sh** bash script in the installation directory. This will start the Linux installer.

```
./install.sh
```

The following list details the process of installing Conformiq on your computer:

1. Specify a destination directory for the installation. The default is **$HOME/conformiq**. If the installation directory does not exist, the installer will create one. Make sure that you have required permissions to write to the destination directory.
2. Specify whether you want to install Conformiq Computation Server. The default is **yes**. If you select server installation, the installer will install the server and database components to the destination directory, and initialize the database appropriately.
3. Specify whether you want to install Conformiq Eclipse Client. The default is **yes**.

1 If you select the client installation and you are installing Conformiq Eclipse Client as an Eclipse plugin, the installer will prompt you to specify the location of the Eclipse installation. The default location that the installer looks is in **$HOME/eclipse**.

4. In order to provide a smooth user experience of Conformiq Eclipse Client client, the installer will recommend a few different memory configurations for the Eclipse based client (These configurations are used by the Java Virtual Machine that is responsible of executing the Eclipse. For more information about tuning Java Virtual Machine please refer *Memory Management in the Java HotSpot Virtual Machine* document available online). Select the one that suits your needs the best. If you do not wish to deploy the memory configuration recommended, you can continue without making changes to the configuration. The installer will not

recommend this memory configuration if Conformiq Eclipse Client is not selected for installation.

5. The installer will install the selected set of components to your computer.
6. At your own discretion, you may want to add the directory where Conformiq resides to your $PATH, or create a symbolic link from '/usr/local/bin' or '/usr/bin' to the individual executables.

The Conformiq Computation Server can be started by executing the command `qcs` in the installation directory. For example, after installing QCS to the default location, QCS is started as follows:

```
$HOME/conformiq/qcs
```

As of Conformiq Qtronic 2.1.0, the Conformiq Computation Server is automatically started when the user starts Conformiq Eclipse Client and attempts to establish a connection to Conformiq Computation Server. See the Section How to Configure Conformiq Eclipse Client for more information on how to change this default behavior.

As of Conformiq Qtronic 2.1.0, the Conformiq Computation Server has support for distributing the calculation over multiple CPU's. This feature is always enabled in the installed version and therefore does not need to be activated by the user.

2.5.2 How to Uninstall Conformiq on Linux

- Remove the directory that you originally selected as the destination directory for the installation. For example, if this directory is **$HOME/conformiq**, execute

```
rm -rf $HOME/conformiq
```

* If you created any symbolic links to the executables, remove the symbolic links.

- Remove the Conformiq Eclipse Client "link file" from the Eclipse installation directory. For example, if the Eclipse installation directory is **$HOME/eclipse**, execute

```
rm $HOME/eclipse/links/com.conformiq.qtronic.client.link
```

2.6 Checking the QEC Installation

After Conformiq Eclipse Client has been installed, the next step is to check that the plugin has been properly activated by Eclipse. The most straightforward way is to start Eclipse and select **Window > Open Perspective ...** and check that **Conformiq** is listed there. If not, the most likely reason is that the Java version that Eclipse is using is not recent enough or similar. See Section How to Switch to Conformiq Perspective for more information about Conformiq perspective.

Troubleshooting QEC Installation

If **Conformiq** is not listed in the list of available perspectives explained in the previous section, it is recommended that you start troubleshooting by following the steps detailed below:

1. Select **Window > Show View** and select **Other**. This will open the **Show view** wizard.
2. From **Show view** wizard, select **PDE Runtime > Plug-in Registry**. This will open the **Plug-in Registry** wizard.
3. Locate **com.conformiq.qtronic.client** from the list of installed Eclipse plug-ins. If the plug-in is not listed here, the installation has failed and you must reinstall the Conformiq Eclipse Client. Make sure that you have the appropriate permissions to write to the Eclipse installation directory.
4. If the **com.conformiq.qtronic.client** plug-in is listed in **Plug-in Registry**, check

that the version of the Java compiler that Eclipse is using is 1.6 or higher. In case you have multiple versions of Java installed on your computer, you may need to set your **PATH** environment variable so that it lists Java version 1.6 first before older versions and restart Eclipse.

If after taking the steps above, Conformiq is still not registered in Eclipse, please contact the software provider.

Note that the plug-in registry is not available in all of the Eclipse packages. It is recommended to use *Eclipse Classic*.

Checking the Version of QEC

The version of the QEC plugin can be checked by selecting **Help > About Eclipse SDK**. This will open the **About Eclipse SDK** view where you can select **Plug-in Details** which opens the **About Eclipse SDK Plug-ins** view. This view will list all the plugins that are installed in Eclipse with version numbers. The QEC plugin is provided by *Conformiq Software* and the plug-in name is *com.conformiq.qtronic.client*.

Customizing the Conformiq Perspective

The Conformiq perspective in the Eclipse user interface can be customized in a number of ways. You can, for example, disable and enable some of the command groups in the tool bar.

In order to add or remove command groups from the tool bar, follow the steps detailed below:

1. Switch to the Conformiq perspective, for example by selecting **Window > Open Perspective > Conformiq**.
2. Select **Window > Customize Perspective...**. This will open the **Customize Perspective** wizard.
3. Select the **Commands** tab.
4. Select the command groups that you want to have in the tool bar from the

Available command groups.

Use the steps above if for some reason the Conformiq specific commands are not visible in the tool bar in the Conformiq perspective.

2.7 License Management in Conformiq

Conformiq Designer is license managed software. This means that every time you run Conformiq it checks for an electronic certification of your right to use it. (This does not mean that Conformiq would contact any service outside your company, for instance, a service provided by Conformiq Software at its own domain.)

The purpose of the license management features is not to define what your use rights are in the first place, because this is done in the licensing agreements between you or your company, and the copyright holders of Conformiq. Rather, the license management features help you to abide within the terms of these agreements.

Keeping this in mind, there are three different mechanisms that Conformiq Designer uses to verify your right to use the software:

- The evaluation version of Conformiq Designer makes use of evaluation keys, which are character sequences looking like *APO39-JK119-NCQOL-011LX-ZMNNM*. When Conformiq Designer is running as the evaluation version it will ask for an evaluation key. Evaluation keys have a limited validity time.
- Other versions of Conformiq Designer check for a right to use the software at startup and then regularly until the software is closed.

In the last case, Conformiq Designer needs a license grant, which is a small electronic document (actually, a block of a few lines) that certifies that Conformiq Designer can be used in its present configuration at your local computer node. Conformiq Designer can get access to this license grant in two ways:

- You can select the license file in Conformiq Designer via the GUI's license

management features. The license grants fed in by this method are usually long-term, node-locked grants. This is known as node-locked licensing.

- Conformiq Designer can automatically check out the grants as short-term, renewable grants from a license server. Conformiq Designer supports both Flexera based license server and a simple web-based license server (but the license server usually resides at your intranet server rather than on the public Internet). This is known as floating licensing.

As already implied, there exist different configurations of Conformiq Designer. These configurations are not shipped or installed separately. Instead, Conformiq Designer can be configured dynamically to run in any of these configurations. However, because different configurations have different licensing requirements, probably not all of them are actually usable for you. If you select a configuration that you do not have a license for, Conformiq Designer will not work properly but will prompt you about a missing license and guide you to reconfigure the product.

Licensing applies to Conformiq Eclipse Client, not to Conformiq Computation Server. Conformiq Computation Server components can be installed freely on as many nodes as you want.

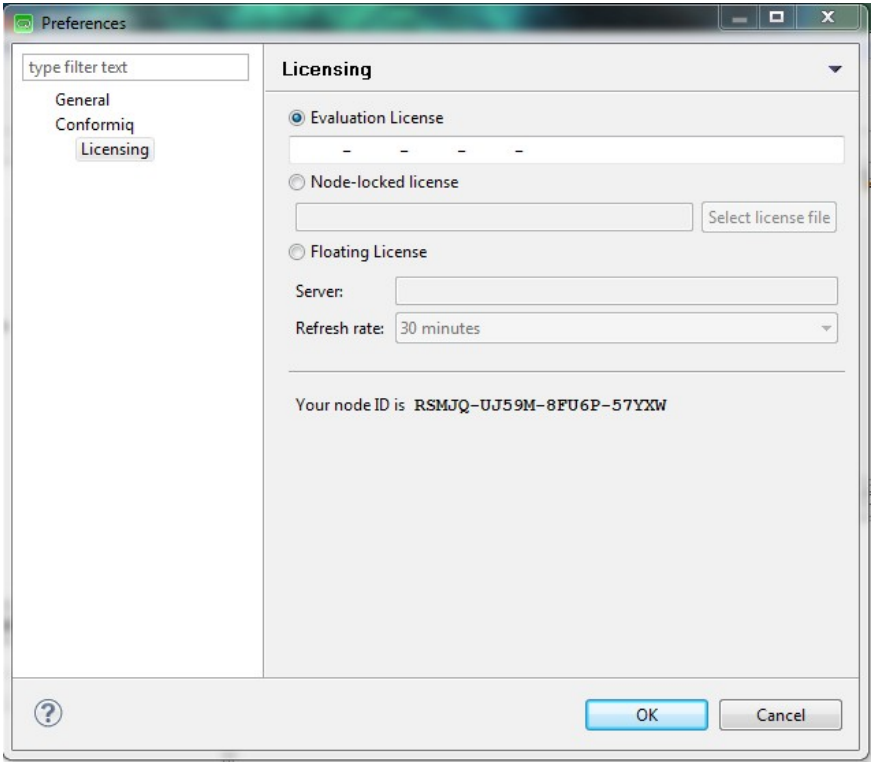
2.7.1 Configuring Conformiq Feature Set

If you are conducting an evaluation of Conformiq, choose *Conformiq Evaluation*. In other cases, choose the Conformiq version that matches your node-locked or floating licenses. When in doubt, contact your system administrator.

Conformiq Designer will remember your choice and will not prompt you again for it. However, you can reconfigure Conformiq Designer at your will by

1. selecting **Window > Preferences...** in the main menu. This will open the **Preferences wizard**.

2. selecting **Conformiq > Licensing** from the Preferences wizard. This will open the *Conformiq License Management* view shown in the figure.



Conformiq License Management view

2.7.2 Conformiq Evaluation

Conformiq provides limited time evaluation licenses for the prospective customers who are interested in finding out the suitability for Conformiq Designer to their specific needs and test environments. Prospects can download an evaluation copy of Conformiq Designer from the Conformiq website and request the license online.

If you are conducting an evaluation of Conformiq, make sure you have selected the "Conformiq Evaluation" configuration (see above). If you do not have a valid evaluation license already installed, Conformiq Designer will ask you for one. Enter the evaluation key you have received when prompted. Conformiq Designer will notify you about the remaining evaluation time every time you establish a connection to Conformiq Computation Server.

If you want to change the evaluation key while the current key is still valid, follow the steps detailed below:

1. Select **Window > Preferences...** in the main menu. This will open the **Preferences** wizard.
2. Select **Conformiq > Licensing** from the Preferences wizard.
3. Check the **Evaluation License** check box and enter the license text block.

Most features of Conformiq are available in the evaluation version.

2.7.3 Named User Licensing

If you have a named user license for your configuration and your node, you can provide the license to Conformiq Designer in the license management dialog.

To configure a node-locked license, follow the steps detailed below:

1. Select **Window > Preferences...** in the main menu. This will open the **Preferences wizard**.
2. Select **Conformiq > Licensing** from the Preferences wizard.
3. Check the **Node-Locked License** check box and click **Select license file** to select the license file.

Named user licenses are files usually named as ***.lic** and they contain textual information about the license. Typically you receive this kind of a license via e-mail. Save the license file attached in the message and then select the path to file in Conformiq Designer. Conformiq Designer notifies you whether the license was successfully added or not.

The *named user* is technically identified by reading the login name of the user in effect on a Windows or Linux machine. A named user license can contain (by Conformiq's discretion) multiple user names if there is obvious variation of names, e.g. between Linux and Windows systems, such as "jsmith" and "john".

2.7.4 Floating Licensing

Contractually, a floating network license creates the right to use Conformiq Designer on any node within the licensing business organization, however only on one node at a time.

To employ floating licensing you must have either Flexera based license server or a web-based license server for Conformiq Designer installed. The administration of the server is described elsewhere; this section focuses on the use of Conformiq Designer given that a license server is running.

A license is *leased* from the license server when the user starts to operate with a Conformiq project and will stay that way until the user exits the Conformiq Eclipse Client or closes all the Conformiq projects that are open. Technically, leases are always time-bound and bound to a particular user. Once a lease has been created, it cannot be prematurely terminated i.e. the user cannot explicitly "return" the leased license back to the license server, but instead the lease terminates at the moment of its expiration. A lease on a floating license is automatically refreshed by the Conformiq Eclipse Client, which means that a new lease is issued for the same license on the same node and bound to the same user name as the previously existing lease. This mechanism enables a single user to roll over multiple leases on the same node, enabling the continuous availability of Conformiq Eclipse Client during a working session. When the user exits the Conformiq Eclipse Client, there are no further refreshes on the lease, making the floating license available again after few minutes.

Recall that licensing applies to Conformiq Eclipse Client only, not to Conformiq Computation Server, allowing the user to work simultaneously with multiple projects while still occupying a single license.

To configure the license server for use, follow the steps detailed below:

1. Select **Window > Preferences...** in the main menu. This will open the **Preferences wizard**.
2. Select **Conformiq > Licensing** from the Preferences wizard.
3. Check the **Floating License** check box and enter the base URL for the server. You will receive this base URL from your system administration, as it depends on where the license server has been installed.

If your company is using Flexera based licensing solutions, the URL looks for example "29834@server.company.com". In redundant configuration, it can also be a triple of three license servers separated by comma ",", for example "29834@server1.company.com,29834@server2.company.com,29834@server3.company.com".

If your company is using a simple Conformiq provided web-based license server, then the URL to the license server binary is the "base URL" that Conformiq Designer users must configure into their Conformiq installations; for example, "http://server.company.com/cgi-bin/cgiserver.exe". See Section License Server Management for more information.

You can also select the refresh interval for your floating license in the Conformiq Licensing Preferences. Suppose you select an interval of one hour. Then Conformiq Designer will initially check out a local license grant for one hour from the license server. This grant is valid for an hour, and during this time you do not need to be connected to the license server. When half or less of the grant time is left (30 minutes or less), Conformiq Designer will try automatically, in the background, to check out a new grant from the server that will supersede the old one. In this way, if you are connected to the server, you will always have checked out a grant for at least 30 and at most 60 minutes.

Usually the license server resides on an intranet web server, so if you have access to the web server from the external Internet, it can be possible that you can check out Conformiq licenses from outside your local network also. How this actually works depends on how your company has organized external intranet access. Please note that Conformiq Designer does not use HTTPS (secure HTTP) for accessing the license server and therefore cannot log in on a secure web server, so you may need to use a VPN solution or a local web proxy.

The floating license mechanism also works when the license server and licensing client do not agree on the current (wall-clock) time, but if the time difference is more than 24 hours in either way, licensing will stop working properly. Also, if you adjust the clock at the licensing client while there are active grants for the client you may find out that refreshed grants will not work properly. In this case you must wait until your local license grants have expired and continue to use Conformiq Designer only afterwards.

If you need to use an HTTP proxy in order to get access to the external network, you can configure Conformiq Computation Server to use the HTTP proxy by setting the **http_proxy** environment variable before running QCS. In Linux you can do this by running **export http_proxy=http://proxy.mycompany.com** in sh/bash/ksh shells and **setenv http_proxy http://proxy.mycompany.com** in csh/tcsh shells. In Windows, the environment variable can be set for example by using the **set http_proxy=http://proxy.mycompany.com** command. If your proxy requires a login then the proxy address needs to be written in the format **http://user:password@proxy.ip.address:port** in the above commands.

2.7.5 Obtaining Node Identifiers

Sometimes you need to be able to obtain the node identifier for your local node manually. The two cases are:

- You are ordering a node-locked license and your supplier must receive the node identifier in order to bind the license to it.
- You are administrating the license server and you are ordering floating licenses for it.

In order to get the node identifier, open the **Preferences** wizard and select **Conformiq > Licensing**. The node identifier is shown on the bottom of the opened page. You can also retrieve the node identifier by running the "Conformiq Node Identification" program (**cq-node-id** in Linux and **cq-node-id.exe** in Windows). This will show a popup window that contains your node identifier. When the popup is shown, the node identifier has been copied to your system's clipboard, so you can immediately paste it in any other application.

The purpose of the node identifier is to reliably distinguish between different machines where Conformiq Designer might be used or where a Conformiq license server might be installed. The node identifier is aggregated from details of the node's hardware devices. It is possible, although not usual, that the hardware devices change in a way that causes the node identifier to change. This may also happen if you enable or disable, for example, wireless network devices from the BIOS. If you are running floating licensing this is not a huge problem because the grants for the old node will expire whenever they were going to expire anyway, after which you can check out grants for the new node. In the case of node-locked licensing you must contact your supplier who will help you to transfer your node-locked license to the new node.

2.8 License Server Management

If you want to provide floating licensing to your users you must install the license server. You have two options, either using almost industry standard Flexera based licensing solution

(previously know as Flexlm or simply Flex), or using simple Conformiq designed web-based license server. Conformiq recommends using Flexera based licensing solutions for big companies, and also if you've already deployed Flexera license server for some other licensed software. In any other case, Conformiq's own web-based license server is usually easier to set-up.

2.8.1 Flexera based license server

To provide floating licenses from an industry standard Flexera license server, you must install Conformiq's vendor daemon named "cqdesign" (.exe) to your license server, and your company's floating licenses. You must copy cqdesign vendor daemon to Flexera license server's directory of vendor daemons, and then restart Flexera license server. For example starting command can be "./lmgrd -c conformiq.lic" where Conformiq provided license file conformiq.lic contains information about your floating licenses.

2.8.2 Web-based license server

This is a CGI (Common Gateway Interface) binary that you install (usually, copy into the file system) into your web server in a location where it can be accessed via a URL.

For example, if you are using the Apache web server you must copy the binary to a directory that has the ExecCGI option set, or that has been set as a general location for CGI scripts by the ScriptAlias directive.

The server CGI binary will establish a license management database when it is run for the first time. The location for this database cannot be changed in order to prevent accidentally running multiple license server copies. On Windows the location is C:\WINDOWS\Conformiq\licserv.db and on Linux /etc/conformiq/licserv.db. On both operating systems the database file is a regular file.

The web server must have write access to the directory and the database file when it is executing the CGI binary.

The license database is actually an SQL database that resides inside the file. If you try to modify the contents of the database by hand you will end up in a situation where the server says that the integrity checks for the database fail. At this point the database has been rendered unusable and the license server ceases to work. Do not modify the database by hand.

Once you have installed the CGI binary (cgiserver.exe) to the correct location, you can validate that the installation has been successful by opening the CGI binary via a web browser.

For example, if you installed the binary on an Apache server in its default configuration on server "server.company.com", try to access it via "http://server.company.com/cgi-bin/cgiserver.exe". If the installation has been successful and the database created correctly you will receive a page showing an empty list of licenses and a text box where you can edit text (this box is used for adding permanent licenses to the server).

The URL to the binary (as above) is the "base URL" that Conformiq Designer users must configure into their Conformiq Eclipse Client installations; for example, "http://server.company.com/cgi-bin/cgiserver.exe".

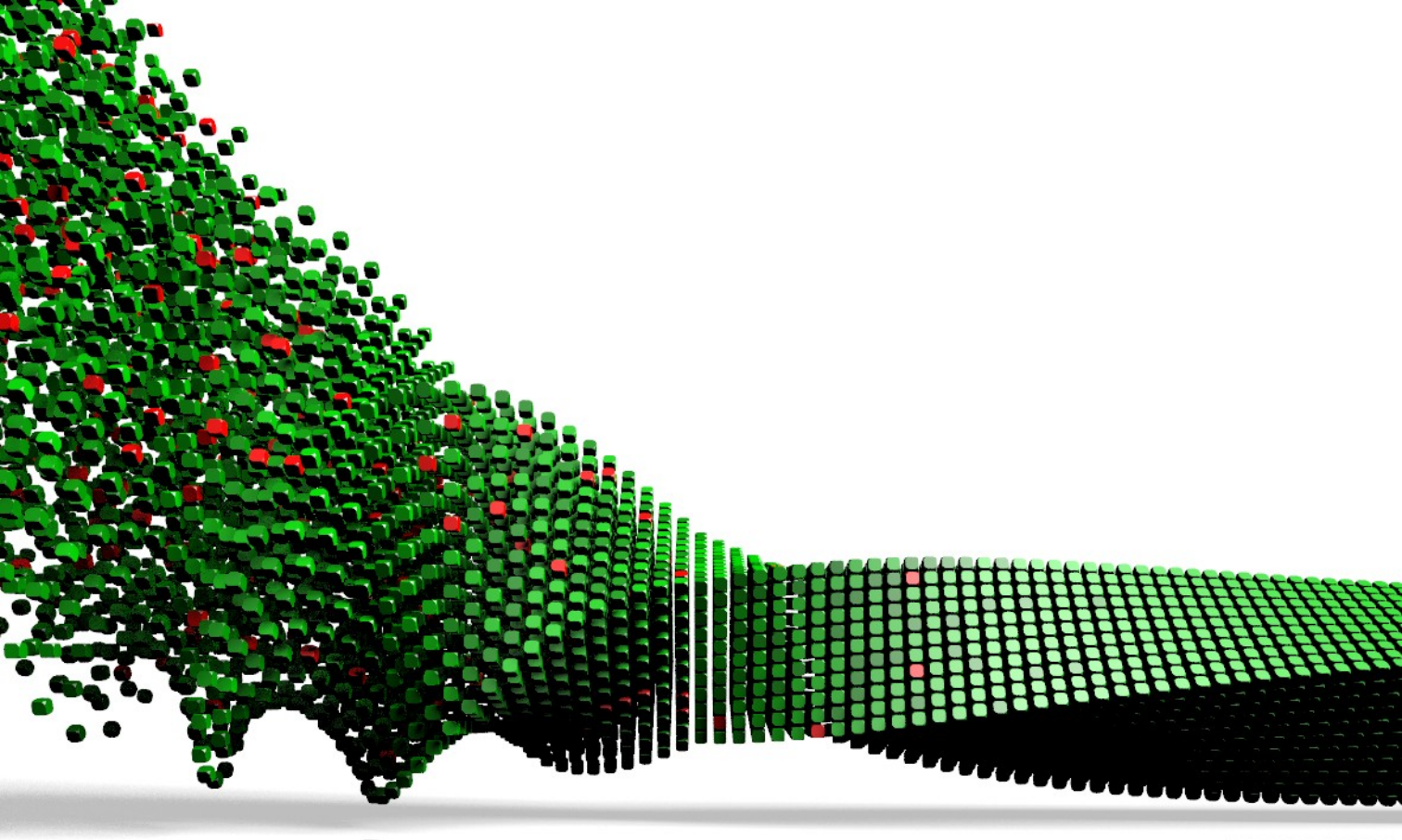
Viewing Licensing Status

To view the licensing status, just open the CGI binary via a web browser. You will receive a list of licenses with their corresponding active grants (if any).

Adding Licenses

To add licenses to the server, cut and paste the license block you have received from your

vendor into the text box that is shown on the status page below the list of licenses and active grants.



3 Testing with Conformiq

Conformiq Designer is a tool for offline generation of test scripts (the particular features available depend on your licensing options). Conformiq Designer creates and executes tests driven by design models. It is not in itself, however, a tool for creating these design models. The reason for this is that Conformiq Designer supports multiple types of design models, and the different types are created and modified using different tools:

- Java/UML models can be created using text editors and Conformiq Modeler, a separate tool that is shipped with Conformiq distribution.
- Models created using some of the leading 3rd-party modeling tools.

To start testing with Conformiq Designer one needs first a *design model* (see Section Conformiq in Software Process). One also needs further *scripting back-end*.

For more information about creating UML/Java models, see Creating Models in QML. Scripting backends are discussed in Creating Conformiq Scripting Backends.

3.1 Quick Start of Using Conformiq

The following list summarizes the steps when working with Conformiq Designer.

1. Switch to the Conformiq perspective by selecting **Window > Open Perspective...** and then **Conformiq**.
2. Select **Window > Preferences...** to configure the license and the Conformiq Computation Server location.
3. Create a new Conformiq project by selecting **New > Conformiq Project**. This will also create a *Test Design Configuration* which 'owns' the coverage settings and scripter plugins.
4. Select model files for the project by either importing or linking them to the project.

5. Import the project's model files into Conformiq Computation Server by clicking **Load model files to Computation Server**.
6. Select coverage goals for the test design configuration that was automatically created when the Conformiq project was created.
7. Select the Conformiq project and click **Properties** to configure *Conformiq options*.
8. Generate test cases by clicking **Generate Test Cases from Model**.
9. Analyze the test generation results in the Conformiq Eclipse Client user interface after the test generation finishes.
10. Select a scripter plugin by selecting the test design configuration and clicking **New > Scripting Backend**.
11. Render the test cases in the format specified by the scripter plugin by clicking **Render All Test Cases**.

3.2 Deploying Example Conformiq Projects

The Conformiq Eclipse Client user interface component comes with a number of example Conformiq projects. These projects can be deployed to Eclipse workspace using the **Examples Wizard**.

Every example Conformiq project contains:

- a set of model files each demonstrating a different modeling challenge,
- pre-configured Conformiq project settings, and
- one or more pre-configured test design configurations.

The following example projects come with the Conformiq distribution:

Echo System

This is a "Hello World" system for Conformiq. It demonstrates a simple system that takes as an input a message from the environment and sends the message

unmodified back to the environment.

Simple End-to-End System

This is an extended version of the "Echo System" that contains two state machines that communicate with each other in the model. The state machine **Receiver** receives a message from the environment, forwards the message unmodified to the **Sender** state machine who then sends the message, once again unmodified, back to the environment. See Chapter Creating Models in QML for more information about state machines.

Triangle

This project demonstrates an example from Glenford J. Myers's book *The Art of Software Testing*. The system receives three integer values as input which are interpreted as representing the lengths of the sides of a triangle. The system then sends an output message that states whether the triangle is scalene, isosceles, or equilateral.

SIP UAC

This example demonstrates the behavior of the client side of the SIP protocol (Session Initiation Protocol, specified in RFC 3261) on an abstract level. SIP is an application-layer control (signaling) protocol for creating, modifying and terminating sessions with one or more participants. These sessions include Internet telephone calls, multimedia distribution, and multimedia conferences.

The SIP UAC model describes the partial functionality of a SIP User Agent Client (e.g. a VoIP phone). The modeled behavior includes call setup, call termination by caller or callee and call cancellation during call setup. The timers associated with these functionalities are also modeled. The SIP UAC model assumes the system under test is interfaced through the phone's user interface and the network.

Inventory System

This example project demonstrates the behavior of an imaginary inventory system. This model specifically shows how you can create tests for a client-server inventory

system by combining a client and a server model. The client's functionality is defined through its user interface and its network messaging. The server behavior is defined through its two different network interfaces, one for the client and one for a management interface. The inventory system model is a model that combines these two models through the common client-server network interface. The generated tests will interact with the system under test through the client's user interface and the server's management interface. Note that both the client and the server models are complete and tests could be created from them by only modifying the model's system block and the main()-function.

The example projects can be deployed to your current Eclipse workspace as follows:

1. Select **File > New > Example...**. This will open the **New Example wizard**.
2. Select **Conformiq** and an example project you wish to deploy to the current workspace. Click **Next**.
3. In order to prevent project name clashes, the New Example wizard will ask the user to give a name to the project. After naming the project, click **Finish**.

The Conformiq Eclipse Client user interface will now deploy the project to the current Eclipse workspace.

After an example project has been deployed, the user can experiment with the actual test generation. The test generation can be started by selecting **Conformiq > Generate Tests** as detailed in Section How to Generate Tests. After the test generation completes, you can analyze the test generation results in the Conformiq Eclipse Client user interface. For more information about the analysis of the test generation results, please refer to Section How to Analyze Test Generation Results.

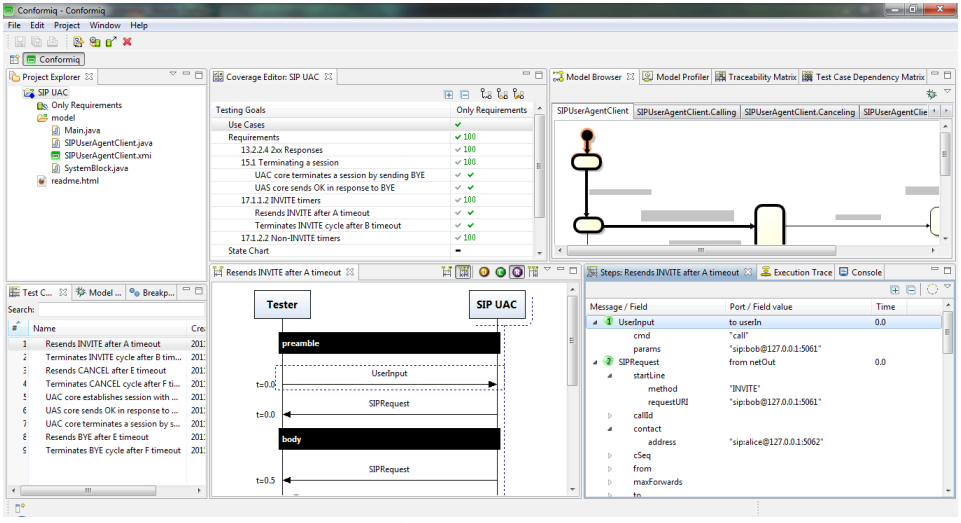
The usual flow in testing with Conformiq Designer is very simple as shown in the next few how-to's.

3.3 How to Switch to Conformiq Perspective

The Conformiq perspective in Eclipse is a group of views and editors in the Workbench window. The Conformiq perspective can exist in a single Workbench window with other perspectives.

Switching to the Conformiq perspective is carried out by selecting **Window > Open Perspective > Conformiq**. If the Conformiq perspective is not visible after selecting **Window > Open Perspective**, select **Other...** from the drop down menu where **Conformiq** is shown.

The Conformiq perspective looks as shown in the Figure. The different views and editors are covered in detail in the following sections.



Conformiq Eclipse Client

3.4 How to Configure Conformiq Eclipse Client

As test generation is carried out by a Conformiq Computation Server, the Conformiq Eclipse Client must be configured with a Conformiq Computation Server address and TCP port number before loading models or generating any test cases.

As of Conformiq Qtronic 2.1.0, the Conformiq Eclipse Client can be configured to use a "Local computation server" or a "Remote computation server".

Local computation server

By default, the Conformiq Eclipse Client always accesses a Conformiq Computation Server running on localhost listening on TCP port 2727. If a server is not running when the client attempts to establish a connection with it, a server is started automatically. This automatically started server is only for local use and will not accept remote connections from other computers on the network. This server will also be shut down automatically together with the Conformiq Eclipse Client. If you want to have a server which keeps waiting for and accepting connections from multiple clients on different computers, then it is necessary to start a server from the Start menu.

Remote computation server

The Conformiq Eclipse Client can also be configured to use a Conformiq Computation Server running on a remote host. The server address can be either a hostname or an IP address. By default, the TCP port number that the Conformiq Computation Server uses is 2727. It is perfectly valid to enter "localhost" as a remote computation server, but this will disable the automatic starting of a Conformiq Computation Server on localhost if no server is running.

Test generation is a computationally intensive task and therefore it is recommended to run Conformiq Eclipse Client and Conformiq Computation Server on distinct computers. The recommended setting is thus "Remote computation server".

In order to change the settings, follow the instructions given below:

1. Open preferences by selecting **Window > Preferences...**.

2. From *Preferences*, select *Conformiq*.
3. Select "Local computation server" or "Remote computation server" based on your setup and preferences
4. In case you select "Remote computation server"

1 Enter the address and the port number of the Conformiq Computation Server.

2 Choose whether you wish to utilize any CPUs from the client workstation for running your test generation tasks by adjusting the “Use additional CPUs from this node” slider. These CPUs will be added to the cluster for running test generation tasks started from this workstation (but not from any other node on the network). You may choose a value between zero and the (automatically detected) number of CPUs available on the workstation.

The "Use additional CPUs from this node" setting will apply independently to every test generation task started from the client. This means that a new test generation task will try to use the given number of CPUs even if there is another task started from the client already running. If you intend to run several test generation tasks from the same client at the same time, consider lowering the number of CPUs to reserve for a single task (before starting any of the tasks) to avoid unnecessary load on the system.

Note that if you have used local computation services (ie you have used 'Local computation server' or you have selected 'Use additional CPUs from this node') when changing the Conformiq computation settings, you may need to manually terminate the local computation services now.

The location of the Conformiq Computation Server is an *Eclipse workspace* specific setting, therefore all Conformiq projects in an Eclipse workspace share

the same Conformiq Computation Server location. See Section Managing Conformiq Projects for more information about Eclipse workspaces.

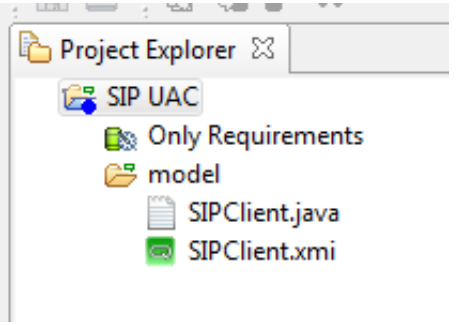
3.5 How to Work with Conformiq Projects

Testing setups are managed as projects in the Conformiq Eclipse Client. They are structural units that can be opened and closed. Conformiq projects contain the following information:

- Model files
- Test design configurations
- Test generation options

In order to create a new Conformiq project, follow the steps below:

1. On the main menu bar, select **File > New Conformiq Project**. The New Project wizard opens.
2. In the **Project name** field, enter the name of the new Conformiq project.
3. Click **Next**. This will open the **Deploy Model Files** page which can be used to automatically generate skeleton model files in addition to a new Conformiq project.



An example Conformiq project in Eclipse Project Explorer

The **Deploy Model Files** page has a checkbox with title *Deploy default model files* that is unchecked by default. If you decide to leave the checkbox unchecked and click **Finish**, a new Conformiq project will be created which will be visible in the Project Explorer. Note that this operation will also create a single *Test Design Configuration*. (More information about Test Design Configuration is given in Section How to Create Test Design Configurations). If you, on the other hand, wish that the Conformiq Eclipse Client would also automatically generate a set of skeleton model files for you, the option can be checked. When the option is checked, the next step is to enter the name of "the main class" to the text box titled **Name of the main class**. This name will be used by the Conformiq Eclipse Client to create an active class with a state machine that has the given name. Note that this name must be a valid Java identifier. Once the name has been entered, click **Finish**. This will, in addition to creating a new Conformiq project with a single test design configuration, populate the *model* folder with the four files detailed below (note that in all the files shown below, the name *MainClass* is substituted with the user supplied name of the main class):

- SystemBlock.cqa which will contain the definition of a system block with commented out examples of how you can then add the ports and records to the file.

```
/** Declaration of the external interface of the system being modeled. This is
    specific to system modeling; a similar construct does not appear usually in
    programming languages. In this "system block", we initially declare one
inbound
    interface (in) and one outbound interface (out). The identifiers 'in' and
    'out' are the names for the interfaces in the model. After the colon we
    list the types of records that can possibly go through the interface in
    question. */
system
{
    Inbound in : MyMessage;
    Outbound out : MyMessage;
}

/** Declaration of a message type, which is technically presented as a "record
    type". It is a record of pure data. This record type 'MyMessage' is empty,
    i.e. it does not contain any actual data fields. */
record MyMessage { }
```

- Main.cqa which will contain the main entry point as follows:

```
/** Main entry point to the model i.e. the place where the system "starts". */
void main()
{
    // Instantiate the 'MainClass' and start execution of the state machine.
    MainClass mc = new MainClass();
    mc.start("MainClass");
}
```

- MainClass.cqa is generated based on the user-specified name of the "main class" with the following content:

```
/** Declaration of the 'MainClass' state machine. This state machine has its
    own execution thread and it supports communication with other state
    machines via ports. */
class MainClass extends StateMachine
{
    /** The default constructor. */
    public MainClass() { }
}
```

- MainClass.xmi which will contain a state chart corresponding to the main class with an initial state, a basic state named "State1" and a transition from the initial state to the "State1".

In order to close a Conformiq project, follow the steps below:

1. Select the Conformiq project in the Project Explorer view.
2. Click **Close Project** in the pop-up menu.

It is recommended that you close any Conformiq projects when you are not working with them, because the closing of a Conformiq project will free some resources from the Conformiq Computation Server.

To re-open the Conformiq project:

1. Select the Conformiq project in the Project Explorer view.
2. Click **Open Project** in the pop-up menu.

To delete a project and remove its contents from the file system:

1. Select the Conformiq project to be removed in the Project Explorer view.
2. Click **Delete** on the pop-up menu.
3. In the dialog that opens, select **Also delete the contents under ...**
4. Click **Yes**.

If you do not wish to delete the contents, simply select **Do not delete contents** from the opened dialog.

If the model files and scripter plugins are imported to the project (the process of adding model files and scripter plugins to the project is explained later), the original files are left intact even if you choose **Also delete the contents under ...** in the dialog window.

See Section Managing Conformiq Projects for more information about Conformiq projects.

3.6 How to Select Models

Each Conformiq project contains a folder called **model**. This is where the model from which the tests will be generated will reside.

The manifest file concept used in Conformiq Qtronic 1.X is no longer used and the model files are individually selected for the project instead of a single manifest file.

The first step in importing the model into Conformiq Designer is to add model files to the **model** folder. There are a couple of ways to do this:

The first option is to actually copy the model files into the Conformiq project. This means that the original model files and imported model files are totally distinct, thus changes are not reflected automatically between these physical resources. The steps to import model files into a Conformiq project are detailed below:

1. Select the **model** folder under a Conformiq project in Project Explorer.
2. Select **Import** from the pop-up menu. This will open the Import wizard.
3. Select **General > File System** and click **Next**.
4. Click the **Browse** button on the opened page to select the directories from which

to add model files. Click **OK** once the directory has been selected.

5. From the pane on the right hand side select those files that are part of the model and click **Finish**.

The second option is to create a link to the model files in the file system. This means that the Conformiq project does not contain the model files, but just file links to them. The steps to create file links to the actual model files are detailed below:

1. Select the **model** folder under a Conformiq project in the Project Explorer.
2. Select **New > File** from the pop-up menu. This will open the **New File** wizard.
3. Click **Advanced** and check **Link to file in the file system**.
4. Select **Browse...** which will open a file selector.
5. Navigate to the model file and select **OK**.
6. Finally click **Finish** in the New File wizard.
7. Repeat the steps above for each file that is part of the model.

A convenient way to work with linked resources is to use path variables which are used to specify locations on the file system. The location of linked resources may be specified relative to these path variables. By using a path variable, you can share projects containing linked resources with team members without requiring exactly the same directory structure as on your file system.

In order to specify a linked resource in a parent directory as being relative to a path variable, you must use the following syntax `${PATH_VARIABLE}../../MyResource.txt`. Please note that there cannot be a slash (`/`) character between the path variable name and "`..`".

Path variables are created as follows

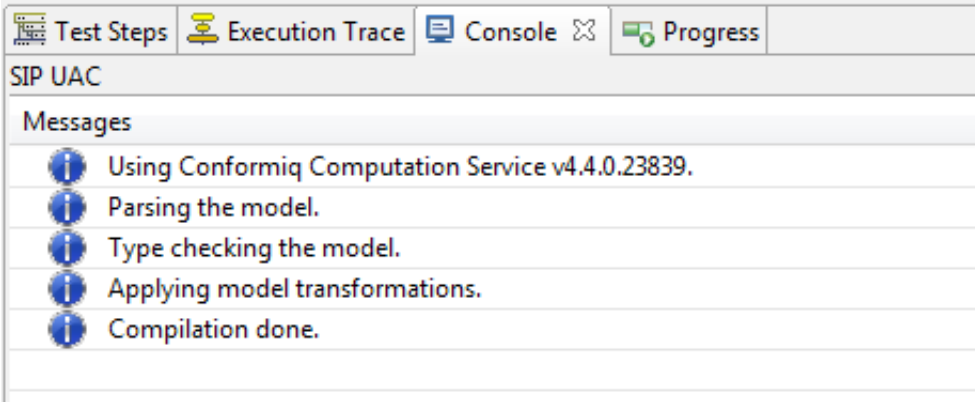
1. Select **Window > Preferences...**. This will open the **Preferences** wizard.

2. Select **General > Workspace > Linked Resources**.
3. Select **New...** and enter the name of the new path variable and the location.

Now when you link a model file to your Conformiq project, you can do it by using this path variable. Instead of defining the absolute path to the model file, you select the path to the model file that is relative to the path variable. This way, when other members of your team use the same Conformiq project, they can redefine the path variable to point to a proper location in their file system.

See Section Managing Conformiq Projects for more information about Conformiq projects.

Once the model files have been imported from the file system to the Conformiq project, the model can be loaded to the Conformiq Computation Server by selecting **Load Model** in the tool bar. This will send the model files to the Conformiq Computation Server, which then imports the model. The status information in addition to warning and error messages is shown in the Eclipse Console.



Eclipse console showing results of successful model import

Model files are always inserted into the **model** folder. This is where Conformiq Designer will look for model files, nowhere else. Within the model folder, you

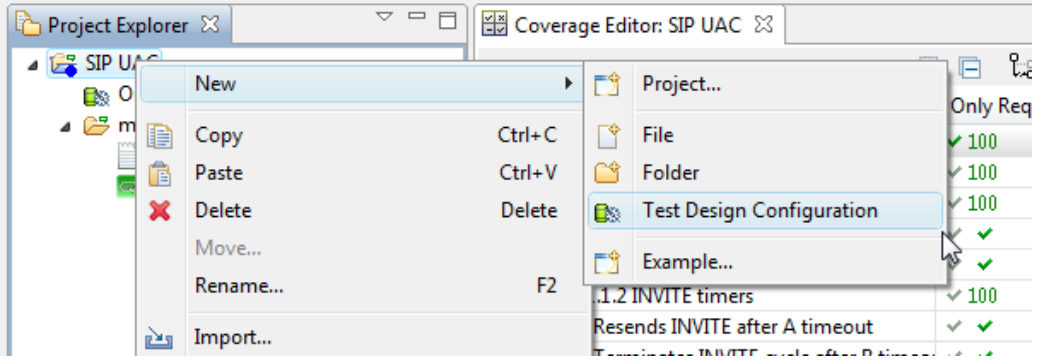
can have a directory hierarchy so that logically distinct model parts (such as server components and client components) can be placed into different subdirectories. Note, however, that all the files under the model directory are treated as part of the model; therefore you cannot place, for example, documentation files under the model directory.

3.7 How to Create Test Design Configurations

Test design configurations were introduced in Conformiq Qtronic 2.0. Test design configurations allow the user to create different profiles with different coverage settings and scripter plugins for different testing purposes. For example, the user may wish to have a test suite for verifying very basic requirements of the system and another test suite for verifying very detailed corner cases such as boundary values of integral comparisons and the like. In this particular case, the user can define two distinct test design configurations to a single Conformiq project: one for verifying the very basic requirements and another for verifying the more detailed corner cases.

Test design configurations contain a set of coverage settings and a (possibly empty) set of scripter plugins. In order to create a new test design configuration for a Conformiq project, follow the steps below:

1. Select the Conformiq project in the Project Explorer view.
2. Select **New > Test Design Configuration** from the pop-up menu. This will open the **New Test Design Configuration** wizard.
3. Enter the name of the new test design configuration into the **Test Design Configuration name** field and click **Finish**.



Create a new Test Design Configuration

Existing test design configuration can be duplicated via *Duplicate*; The operation creates a duplicate of the given test design configiration including the coverage settings, scripting backends, and their settings. The name of the duplicated test design configuration is "<original DC> (copy)", so for example a duplicate of "DC 1" will be named as "DC 1 (copy)". Naturally the name can be changed via *Rename*. In order to create a duplicate of an existing test design configuration, right click the test design configuration in the Project Explorer and select *Duplicate* from the context menu.

Note that when a Conformiq project is created, a single Test Design Configuration is created by default. For more information on creating and working with Conformiq projects, refer to Section How to Work with Conformiq Projects.

3.8 How to Create Use Cases

Conformiq Designer offers the ability to specify **use cases** separately from the modeled behavior – sometimes also referred to as test purposes. These use cases represent partial or full sequences of messages exchanges with restrictions on data based on the specified system interface and they are used to describe a particular model behavior, i.e., a run of the model.

A use case in Conformiq describes essentially high level, usually partial I/O sequence that a system under test (i.e., the black box) is expected to reproduce. For each message in such a

sequence the message type and the port (as specified in the system interface specification of the model capturing the system operation) and expected time stamp have to be specified. By default any message contents are accepted for a message but can be refined by further constraining the message field values to specific values. Secondly, one or more so called “gaps” can be inserted into any point at these sequence to express that any messages can arrive or be sent on any port before the next message in the sequence occurs in a generated test. Besides the reuse of the system interface specification, use case specification is completely independent of the specification of functional behavior, i.e., it is possible to specify use case or (partial) message sequences that do not comply or violate to specified system operation.

3.8.1 Why Create a Use Case

Use Cases can be used to select specific data values to generate tests or to select specific test sequences to be part of the generated test suite. In addition, the Use Cases can be used in some cases to guide Conformiq's test generation heuristics over computationally hard spots in the model without increasing look ahead depth (See Section How to Configure Global Testing Parameters for more information about lookahead depth option), and thus decreasing the time required in the test generation.

Use Cases as "coverage items"

Conformiq Designer supports several different test generation heuristics that are used to aid in selecting a good set of tests; requirement, state, and transition coverage, just to name few. A Use Case that describes a run is used as a test generation heuristic providing further coverage items for the test generation to consider when carrying out the actual state space expansion and in test selection. What we are interested in here is to see that the generated test suite also covers the identified Use Cases.

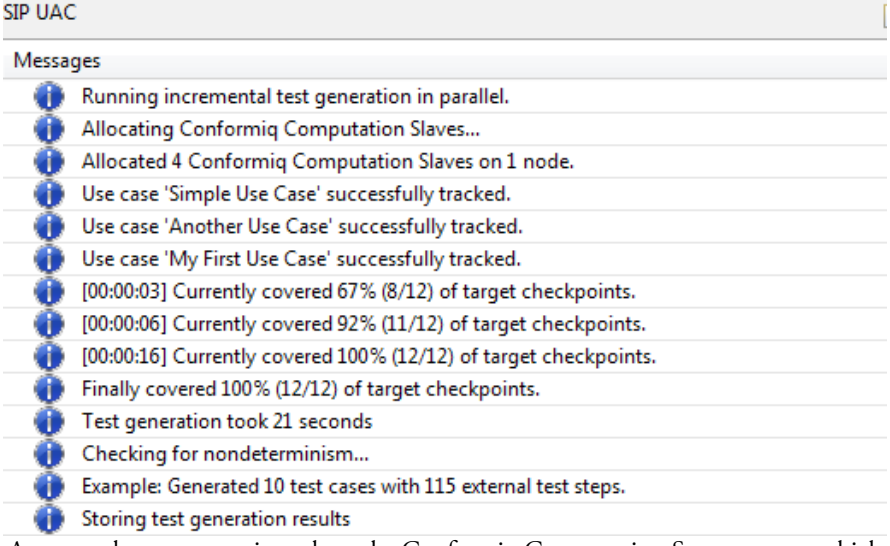
Use Cases are "extended functional requirements"

Functional requirements are textual annotations in the model that are used to establish direct links to identified functional requirements (see Section

Requirements on how to use `requirement` keyword). Functional requirements can be quite elaborate for describing a sequence of steps that needs to be taken in order to fulfill the requirement. Therefore, Use Cases can be used to model more elaborate functional requirements that describe (partial and abstracted) sequences of steps.

Use Case can be used to guide test generation

Sometimes Conformiq Designer does not generate tests for a particular part of the model because these model parts are outside of what the tool can see and reach within the "look ahead". For example, a behavior that can be reached by taking a certain action several times, none of which adds to the coverage. Use Case can be used to guide and steer the test generation algorithm to reach these areas in the model by giving it explicit instructions on how to expand the state space.


SIP UAC
Messages
Running incremental test generation in parallel.
Allocating Conformiq Computation Slaves...
Allocated 4 Conformiq Computation Slaves on 1 node.
Use case 'Simple Use Case' successfully tracked.
Use case 'Another Use Case' successfully tracked.
Use case 'My First Use Case' successfully tracked.
[00:00:03] Currently covered 67% (8/12) of target checkpoints.
[00:00:06] Currently covered 92% (11/12) of target checkpoints.
[00:00:16] Currently covered 100% (12/12) of target checkpoints.
Finally covered 100% (12/12) of target checkpoints.
Test generation took 21 seconds
Checking for nondeterminism...
Example: Generated 10 test cases with 115 external test steps.
Storing test generation results

An example test generation where the Conformiq Computation Server reports which Use Cases it has successfully tracked during the test generation

3.8.2 Basic Features of a Use Case

No Modeling Required to Define a Use Case

Use Cases are described in the Conformiq Eclipse Client user interface and you do not need to define a separate Use Case model to capture a Use Case.

Data Abstraction

A Use Case can be described without giving actual values for all the data. Instead, a data value that we do not care about in the Use Case can be abstracted by explicitly saying that the given data item can have any value.

Partial Behavior

A Use Case does not need to be a full trace starting from the beginning of the system model containing all the steps that we need to follow in order to run the Use Case. Instead, a Use Case can be partial so that the Use Case does not need to start from the beginning of the system model. In addition, it is possible that some of the steps are totally omitted in the Use Case.

How To Manage Use Cases

Coverage Editor (See Section Coverage Editor) is used when creating Use Cases. The Coverage Editor contains a top level hierarchy, **Use Cases**, which can contain folders and individual Use Cases. Using Coverage Editor, you can

Add Folder

You can add folders to the Scenario hierarchy by right clicking the folder within the hierarchy and selecting "Add Folder" from the context menu.

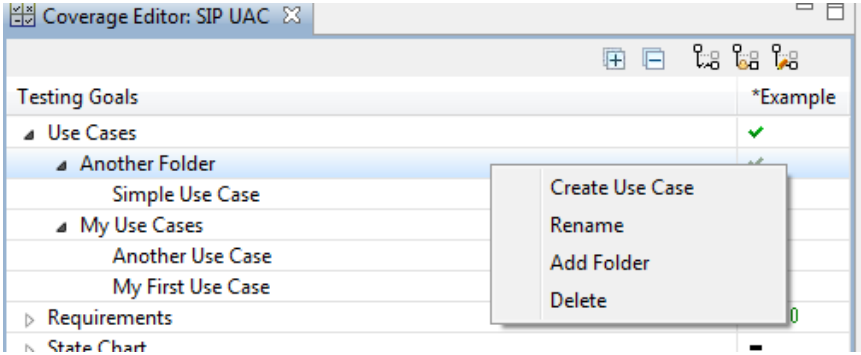
Delete Folder

You can remove a folder by right clicking the folder and selecting "Delete" from

the context menu. If the folder is not empty, the "Delete" action will prompt a question whether to delete also the Use Cases and Use Case Folders within the folder as well.

Rename

You can rename the folder by right clicking the folder and selecting "Rename" from the context menu. If there is a name clash, the renaming will fail



An example Conformiq project with two Use Case folders

How to Create Use Cases

An empty Use Case is created in the Use Cases hierarchy by right clicking a folder in the hierarchy and selecting "Add New Use Case". The operation gives a default name to the Use Case which is "Use Case (n)", where n is smallest value that makes the Use Case unique.

You can also convert a test case into a Use Case by dragging-and-dropping the test from the "Test Cases" view to a folder in the Coverage Editor. The same test can be dragged-and-dropped multiple times to the Use Case hierarchy, in which case copies are created. In the case of a naming clash, "(n)" suffix is added for the smallest 'n' such that the Use Case becomes unique.

A Use Case can be duplicated by right clicking a scenario and selecting "Duplicate" from the context menu. The duplicate Use Case is renamed as above and it appears in the same folder.

Each Use Case has a coverage setting; the setting can be TARGET, DON'T CARE, or INHERIT (See Section How to Configure Design Configuration Specific Testing Parameters for more information about the coverage settings). Compared to other coverage goals, Use Cases can be only targeted or ignored, but not blocked or asserted. Conformiq Designer analyzes those Use Cases that are TARGETs or thate INHERITs a TARGET setting.

3.8.3 Defining a Use Case

The actual Use Case is described in terms of external message take-over's, i.e., a Use Cases is a sequence of inputs and outputs typed by records and ports of a model, just as a test case, but with the additional feature that the following items can be marked "don't care":

1. Timing
2. Message field values

A valid Use Case contains at least one message. Between messages it is possible to add a "Gap". A gap denotes zero or more "don't care" messages. Gaps can also be at the beginning or end of the Use Case to denote that more messages are allowed "heading" or "trailing" the messages. Note that there is always an implicit Gap at the end of each Use Case.

The Use Cases are defined directly in the Conformiq Eclipse Client user interface in the "Use Case Editor" and require no modeling efforts. The following set of actions can be performed via the Use Case Editor:

Add Message

New messages can be added at any point in the sequence. You can select a port and a record type from pull-down menus. The record is added with all fields set to "any value". The port defines the direction of the message (input/output) and, for convenience; this is indicated in the left hand side of the view with an arrow icon. The wall clock value is set to "any value" as well. The content of pull down menus is empty before the user loads the model for the first time.

Fill / Edit value

You can change a field/timer value from "don't care" to a defined field/timer value. If you fill a field value, a default value for the given field is filled in. If you fill in the timer value, the timer value of the previous defined message is filled by default. If you fill in the timer value of the first field, the timer value is by default set to 0.0. It is an error to set a smaller timer value from a previous message and any attempt to do so will cause an error "Invalid value for timer. Timer value must be equal or greater than the timer value of a previous message".

When editing a String field, you must leave the quotation marks out so instead of entering for example *"Hello World"* you should enter simply *Hello World*.

Add "Gap"

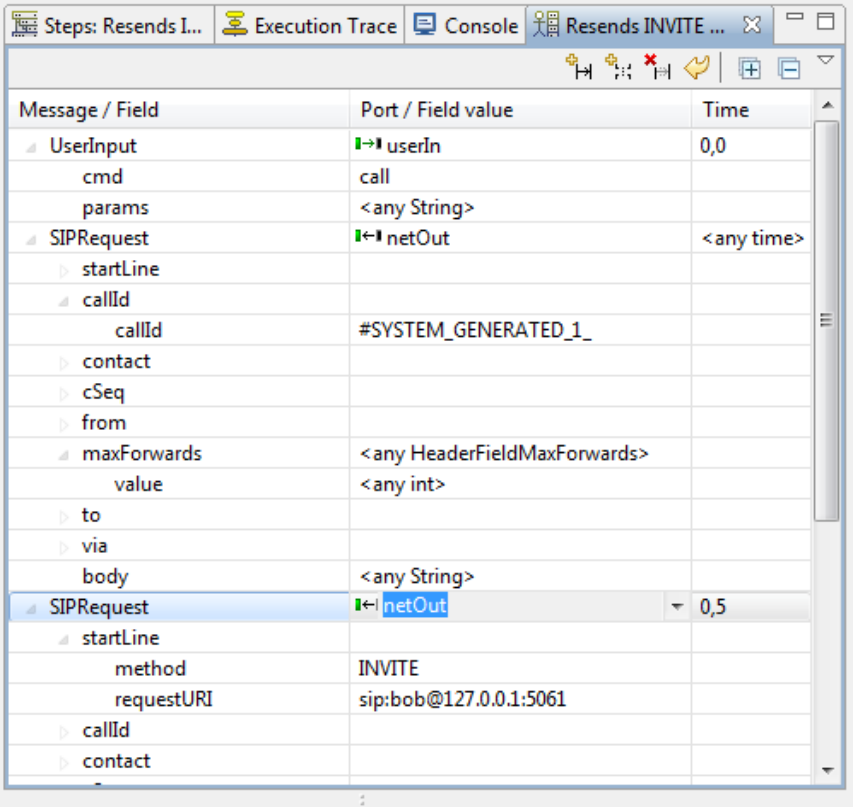
Between messages, it is possible to add a "Gap". A gap denotes zero or more "don't care" messages. Note that Gaps can be also at the beginning or the end of the Use Case to denote that more messages are allowed "heading" or "trailing" the messages. An implicit Gap is always added to the end of the Use Case.

Remove Message / Gap

You can remove any individual message from the Use Case. If the removed message is between two Gaps, the Gaps are merged in to one automatically.

Undo

You can undo the previous actions via the Undo action



Defining the Use Case via the Use Case Editor. Note that in the Figure, the method field is of type String and we have omitted the quotation marks from the string literal and entered simply *INVITE*

3.8.4 Updating a Use Case

During the modelling effort, it might be required to add, remove or modify fields of the records of the SUT interface. If such changes are made, the changes usually affect also use cases. After reloading the model, new record fields are automatically added to all use cases with "any value" as content. If you remove or rename some field, the field with an obsolete

name and a value shows in red, and you can remove the red field by right clicking and selecting "Delete" from the context menu or simply pressing "Del" key when such an obsolete red field is selected. Before removing a field, the value should be checked and depending on the semantics of the model, a value of some other field might require modification to preserve the semantics of the Use Case.

Also, a use case with obsolete field names shows up as red in Coverage Editor too. Those use cases will be ignored during the test execution until you remove all obsoleted red fields.

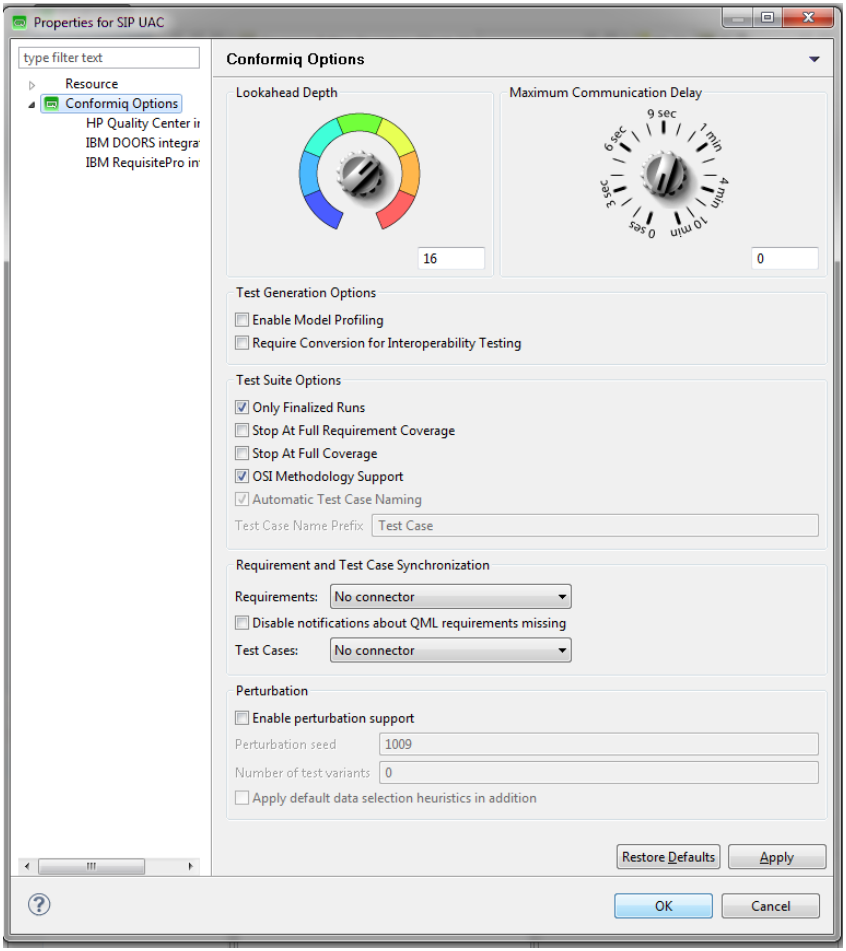
3.9 How to Configure Test Generation

There are two different "types" of test generation parameters in Conformiq Designer: those that are general and global across different test design configurations, and those that are bound to specific test design configurations. For example, the concepts of *lookahead depth* and *only finalized runs* are generic as they are properties that evolve from the model.

3.9.1 How to Configure Global Testing Parameters

To modify the project wide testing parameters, follow the steps shown below:

1. Select a Conformiq project in the Project Explorer.
2. Select **Properties** from the pop-up menu. This will open the **Properties** wizard.
3. Select **Conformiq** from the left hand side of the view.



Configuration view for *Conformiq options*

The properties shown in the view are as follows:

Lookahead Depth

Controls the amount of lookahead for planning the test scripts. The value of the lookahead corresponds to the number of external input events to the system or

timeouts. Selecting values from the left correspond to lower lookahead values. When Conformiq Designer plans the tests, it intellectually selects interesting values for data based on the logic in the design model. If the logic that manipulates the data is after a certain number of external events, the lookahead value must be increased, as Conformiq Designer must be able to "see" this in order to make decisions on the data values. If you set this value too low you can miss some tests (of course, you will see this from the coverage reporting). On the other hand, having the value too high can cause very high test generation times. Therefore, reasonable values for lookahead depth are recommended and you should always start with the lowest possible value. Practically, usually the third level (color cyan) is the highest that you need to go and if this is not sufficient, it is likely that there is some problem in the model. (Note that Lookahead Depth can also be increased locally only for a certain model part using a QML modeling language construct `cq_increase_lookahead()` described in Section Miscellaneous Functions)

Maximum Communication Delay

Defines the communication slack, i.e., the time interval in which it is OK to deliver a message. Recommended values are from 3 to 10 seconds, but this depends on your application. As a rule of thumb, the latency value should be at most 1/2 of the granularity of timeouts in your system, if any. For example, if your system has a timer that expires in ten seconds, you should not use a latency value higher than 5 seconds.

Enable Model Profiling

This option is used to enable or disable the integrated model profiler which provides guidance for optimizing Conformiq models by pinpointing their problematic constructs, i.e., those model parts on which Conformiq Designer spends most of its time. See Section Model Profiler for more information.

Require Conversion for Interoperability Testing

When this option is selected, a `require` statement is handled as an `assert` statement instead whenever it is evaluated in a named thread which was last

awakened by receiving a message from a named thread; or in a thread which was last awakened by a timeout when it was not waiting for any external interfaces. The rationale with this feature is that the best practices of Conformiq modeling state that a `require` should happen as soon as possible. So when a `require` imposes something on an incoming message (the common case), it should happen immediately after the message has been received. Given that, in general a `require` pertains to the last message received, therefore if the last message received is an inter-component message (from a named thread to a named thread), the require can be assumed to be related to that. See Section Assertion Like Functions for more information about `require` and `assert` statements.

Only Finalized Runs

When 'Only Finalized Runs' is selected, Conformiq Designer will only generate test cases that end the system in a "clean" state. When this setting is activated, only such test cases are accepted to the generated test suite that would cause all threads in the model to terminate. In practice, this usually means that a main statechart has entered one of its final states.

Stop at Full Coverage

When 'Stop at Full Coverage' is selected, the test generation is automatically stopped **immediately** upon reaching 100% overall coverage (ie. all the TARGET goals have been reached).

Stop at Full Requirement Coverage

When 'Stop at Full Requirement Coverage' is selected, the test generation is automatically stopped **immediately** upon reaching 100% requirement coverage (ie. all the TARGET requirements have been reached). This option takes *precedence* over *Stop At Full Coverage* option, therefore selecting *Stop At Full Requirement Coverage* disables *Stop at Full Coverage* and will cause the test generation engine to automatically stop when reaching 100% requirement coverage and not to continue until 100% overall coverage has been attained.

Note that when *Stop At Full Requirement Coverage* or *Stop At Full Coverage* have been selected **it is not guaranteed that the test suite is stable across multiple test generation runs**, therefore it is not advised to enable these if stability of the generated test suite is of importance.

OSI Methodology Support

Selecting this option activates the "OSI Methodology" feature which provides support for generating test suites conforming to the OSI methodology for organizing test cases as laid out in the ISO 9646-1 standard. The following applies when the feature is enabled: (1) all the generated test cases are divided into three sections: *Preamble*, *Body*, and *Postamble*, (2) every generated test case is automatically named by the name of one of the requirements that is verified in the *Body*, except if the *Body* does not verify any new requirements, in which case it is named by the name of one of the structural checkpoints that is verified in the *Body*, and (3) the generated test cases are ordered in dependency order, so that typically later test cases depend on earlier ones but not vice-versa. See Section How to Generate Tests for more information about test selection and ISO 9646-1 Test Organization support.

Automatic Test Case Naming

This option is used to enable the "intelligent test case naming" feature that aims to select meaningful names for the test cases based on the model structure that each test case covers. See Section Intelligent Test Case Naming for more information.

Test Case Name Prefix

This option is used to define the default name prefix that is given to new test cases. This option is only used when the *Automatic Test Case Naming* has been disabled. By default this value is 'Test Case ' which means that when a new test case is generated, they are given names such as 'Test Case 1', 'Test Case 2' and so on. For more information about naming or renaming test cases, please refer to Section

Naming Test Cases.

Enable Perturbation Support

This option is used to enable *Perturbation* support (Perturbation is a Conformiq Designer feature that allow you to generate tests with non trivial data distribution. See Section Perturbation for more information)

Perturbation seed

This option is used to set the seed value for the perturbation algorithm. The value must be integral. (See Section Perturbation for more information) This option is enabled only when *Enable Perturbation Support* is turned on.

Number of test variants

This option is used to set the how many variants of each test case the Conformiq Designer should aim to generate. The value must be integral. (See Section Perturbation for more information) This option is enabled only when *Enable Perturbation Support* is turned on.

Apply default data selection heuristics in addition

This option is used to indicate that Conformiq Designer should generate a test variant that has been generated by applying the default data selection algorithm of the tool. (See Section Perturbation for more information) This option is enabled only when *Enable Perturbation Support* is turned on.

Requirement and Test case Synchronization

The requirement and test management tool integration components are selected, enabled, and configured here. See Chapter Test and Requirement Management Tool Integrations for more information about available integration components and their configuration.

Generic offline test generation parameters may not be changed during offline script generation so these options are all disabled while generating tests.

3.9.2 How to Configure Design Configuration Specific Testing Parameters

Each test design configuration has its own set of *model driven coverage criteria* that is used by Conformiq Designer to select a set of test cases to form a good test suite. The *coverage goals* are used to guide Conformiq Designer to look for certain behaviors from models or to enable certain behaviors, i.e., to generate test cases that "cover" the coverage goals in the model whether they are related to the constructs in state machines (such as states and transitions) or to the constructs in the action language (such as conditional branching or statements). In Conformiq Designer it is defined that a test case covers a certain coverage goal if executing the test against the model itself would cause the goal to be exercised.

Coverage options are organized into a hierarchy where atomic coverage options are contained inside groups. The coverage groups are a way to organize and present atomic coverage options to the user. Each coverage option can have the following setting:

Denotes a *target* goal. Guides Conformiq Designer to look for behaviors that cover each target goal.

Denotes an ignored goal ("do not care"). Conformiq Designer will ignore these goals while generating the tests.

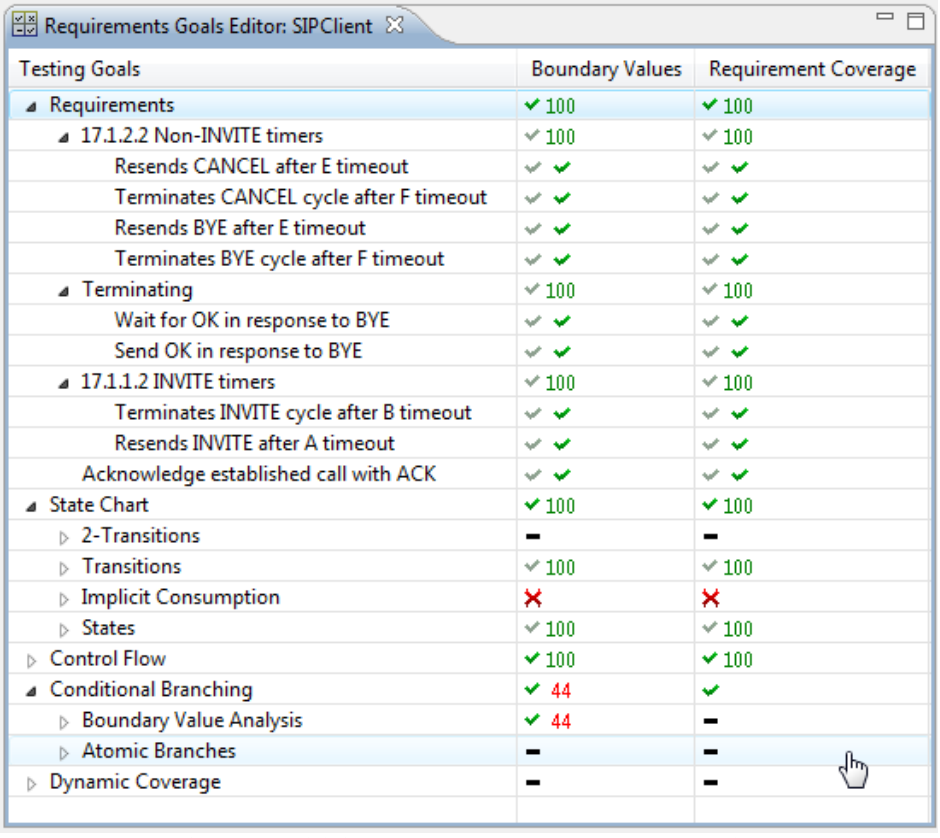
Denotes a blocked goal. Guides Conformiq Designer to omit all the scenarios where the given coverage option is covered. Thus the distinction with **Do not care** and **Block** is that goals marked as **Do not care** can still be covered in the generated tests, they are simply not goals for the tool. Conformiq Designer will not generate a test that would exercise a blocked coverage option, therefore with blocked coverage options the user can prevent

Conformiq Designer from generating test cases that realize certain unwanted test scenarios.

Denotes an assertion goal. Reaching an assertion goal means that the model is fundamentally wrong, thus *internally inconsistent* and causes Conformiq Designer to trigger a run-time error. Assertion goals should be used to mark parts of the model that are logically "impossible" in order to discover modeling errors.

The fifth option is **Inherit**, i.e., the coverage option inherits the setting from the coverage group containing the coverage option.

The **Coverage Editor** is used to edit coverage settings. In order to open the view, double click a test design configuration under a Conformiq project in the Project Explorer. This will open the view as shown in the Figure. Note that the view will contain relevant information only once the model has been loaded to the Conformiq Computation Server. In this view, there are two columns for each test design configuration: the left hand side corresponds to the coverage setting (intention), and the right hand side column corresponds to the current coverage status (result). When the cell is edited (left hand side column), the coverage status will be kept as is, but the test design configuration name in the column header is marked with an asterisk (*). When test generation is finished (completed), this asterisk is removed.



Selecting model driven coverage criteria in Coverage Editor

See Section Coverage Editor for more information about analyzing coverage status information.

With enhanced coverage goal editing features introduced in Conformiq Qtronic 2.0, users have finer grained control over selected structural features, enabling them to set coverage setting to individual structural features: now users can select only

an interesting subset of the structural features instead of having to set none or all of the coverage goals related to a given structural feature.

The following coverage settings are related to state machines and they are not visible if there are no state machines in the model.

State Coverage

Guides Conformiq Designer to look for behaviors that cover every UML level state at least once (not visible if there are no states in the model).

Transition Coverage

Guides Conformiq Designer to look for behaviors that cover every UML level transition at least once (not visible if there are no transitions in the model).

2-Transition Coverage

Guides Conformiq Designer to look for behaviors that cover every pair of two subsequent UML level transitions at least once (not visible if there are no transitions in the model).

Implicit Consumption

Guides Conformiq Designer to test that the system correctly ignores messages that are not handled on any transitions going out from a UML state. A word of warning: enabling implicit consumption may not be what you really want. Without implicit consumption selected, Conformiq Designer focuses testing on the explicitly modeled message handlers. With implicit consumption, Conformiq Designer may also send system messages that are not handled in your UML diagrams.

The following configuration options are related to conditional branching. These options are not visible if there is not such a conditional branching in the model.

Boundary Value Analysis

Guides Conformiq Designer to look for behaviors that cover the boundary value cases for all the arithmetic comparisons. Boundary value analysis is a technique to determine tests covering known areas of frequent problems at the boundaries of input ranges. In boundary value analysis the boundaries partition the input domain and we assume that the system partitions the input into a set of domains in which the system's behavior is similar. Due to this, we assume that if an input from a domain causes an error then all the inputs of that domain will cause a similar error and if an input from a domain does not cause an error, then all the inputs of that domain will fail to produce an error. Based on these assumptions, Conformiq Designer attempts to cover the structure of the input as follows:

- For every arithmetic comparison 'x = y' and 'x != y', cover cases 'x < y', 'x = y', and 'x > y'.
- For every arithmetic comparison 'x < y', cover cases 'x < y - 1', 'x = y - 1', 'x = y', and 'x > y'.
- For every arithmetic comparison 'x > y', cover cases 'x < y', 'x = y', 'x = y + 1', and 'x > y + 1'.
- For every arithmetic comparison 'x <= y', cover cases 'x <= y - 1', 'x = y', 'x = y + 1', and 'x > y + 1'.
- For every arithmetic comparison 'x >= y', cover cases 'x < y - 1', 'x = y - 1', 'x = y', and 'x >= y + 1'.

Branch Coverage

Guides Conformiq Designer to look for behaviors that cover every QML level branch (such as *then* and *else* branches of *if* statements) at least once.

Atomic Condition Coverage

Guides Conformiq Designer to look for behaviors that cover every QML level atomic condition branch (such as left and right hand sides of a Boolean *and*) at

least once. Note that because the modeling language uses short-circuit evaluation for Boolean connectives, there are value combinations that cannot be meaningfully tested in general. For example, in the case of `x && y`, Conformiq Designer will not attempt to generate a test case where 'x' would be false and 'y' would be true. The reason is that the short-circuit evaluation rule will prevent 'y' from being evaluated after it has been found that 'x' evaluates to false, which makes it possible that the value of 'y' may depend on the assumption that 'x' evaluates to true. (Note that 'x' and 'y' can be both, e.g., method calls.)

The following configuration options are related to general control flow.

Method Coverage

Guides Conformiq Designer to look for behaviors that cover every QML level method at least once. Note that this coverage option essentially has no effect on the values passed to methods.

Statement Coverage

Guides Conformiq Designer to look for behaviors that cover every QML level statement at least once.

The following coverage options belong to the "dynamic coverage goals" group, i.e., these coverage goals are calculated by Conformiq Designer on the fly as it analyses the model. Because of this on-the-fly calculation, Conformiq Designer will not give coverage percentage for these goals and these coverage goals do not have an effect on the final coverage figures.

Parallel transition coverage

The parallel transition option is used to guide Conformiq Designer to look for behaviors that cover every parallel transition configuration. The major new benefit of this feature is that Conformiq Designer can generate tests for parallel configurations of components that are modeled as independent components that could interact maliciously in the real implementation. As parallel transition coverage goals are calculated on the fly, multiple instances of a state machine are taken into account also.

The following configuration options are related to *all paths coverage*.

All Paths - States

Guides Conformiq Designer to look for behaviors that cover every *sequence* of UML level states at least once. For example:

1. initial — state1 — state2 — state3 — state4
2. initial — state1 — state3 — state6 — ... — stateN — ...

All Paths - Transitions

Guides Conformiq Designer to look for behaviors that cover every *sequence* of UML level transitions at least once. For example:

1. initial->state1 — state1->state2 — ...
2. initial->state1 — state1->state3 — ...

All Paths - Control Flow

Guides Conformiq Designer to look for behaviors that cover every *sequence* of conditional branches (e.g., then and else branches of `if` statements) at least once.

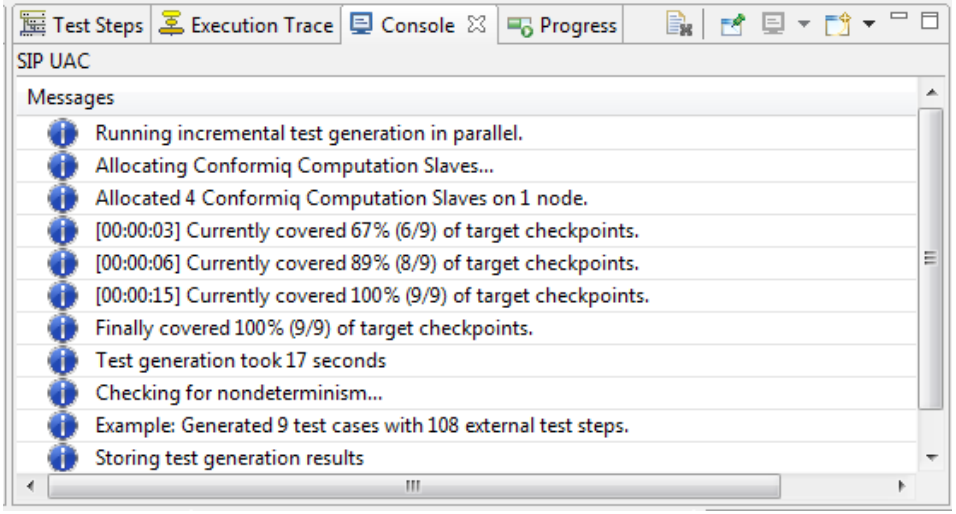
If you have multiple "all paths" coverage options selected, you will get combinations of the above sequences as a result.

In addition to the different coverage criteria based on the structure of the model described above, the user has the option to use *requirements traceability links* to establish additional test goals driven by functional requirements and testing goals. (The requirement links are marked in the model using the `requirement` statement that is an extension to standard Java provided by the QML language. See Section Requirements for more information.). Requirements provide a way to drive test generation by coverage of external functional requirements.

3.10 How to Generate Tests

Once the model files have been selected, the model has been imported to the Conformiq Computation Server, and the coverage settings have been properly set for the test design configurations, the test generation can be triggered by selecting **Update Test Set**. This will trigger the test generation on the Conformiq Computation Server.

As the test generation progresses, the Eclipse console window will show the status of the test generation. In addition, the *coverage editor* will show the coverage status in real-time, i.e., what aspects have been covered so far and what is still left for Conformiq Designer to cover.


Test Steps
Execution Trace
Console
Progress
SIP UAC
Messages
Running incremental test generation in parallel.
Allocating Conformiq Computation Slaves...
Allocated 4 Conformiq Computation Slaves on 1 node.
[00:00:03] Currently covered 67% (6/9) of target checkpoints.
[00:00:06] Currently covered 89% (8/9) of target checkpoints.
[00:00:15] Currently covered 100% (9/9) of target checkpoints.
Finally covered 100% (9/9) of target checkpoints.
Test generation took 17 seconds
Checking for nondeterminism...
Example: Generated 9 test cases with 108 external test steps.
Storing test generation results

Status of test generation shown in Eclipse console

Once the test generation finishes, the final coverage will be shown in the Eclipse console as well as the final coverage of each requirement and structural feature in the coverage editor. In addition, the test generation results will be shown in various views in the Eclipse user interface, a subject of the next section.

Test generation can be stopped manually also before the test generation finishes. This can be done by opening the **Progress** wizard, for example, by double clicking the status text on the

lower right hand side of the Eclipse user interface and by clicking the red box with the **Cancel Operation** label. When the test generation is manually stopped, Conformiq Eclipse Client will present you two possibilities:

- **Merge** the test generation results, meaning that all the generated test cases up until the moment the test generation was stopped are merged into the existing set of test cases.
- **Discard** the test generation results, meaning that all the test cases generated in this test generation run are discarded and the existing set of test cases will stay the same as before.

3.10.1 Test Case Selection in Conformiq

As explained in Chapter Introduction, Conformiq derives tests automatically from system models, i.e., artifacts that represent and model the desired behavior of the system or device under test.

The tool uses *semantics-driven methods* for generating test suites, which means that test generation is guided by deep state space analysis of the behavior implied by the model, instead of being based on syntactic analysis or simple heuristics.

Conformiq is all about creating tests, so the first question one needs to ask is: given a model, what is a valid test case? A valid test case is a series of inputs and outputs that could be produced by simulating the model, and every such series of test inputs and expected outputs can be seen as a test case. It is both a sufficient and necessary condition for being a good test case: that it could be reproduced by simulating the model against a suitable environment.

If one takes it for granted that it is possible to efficiently generate simulations of a system model and thus to construct prototypical test cases, the next question is: how to select a set of test cases to form a good test suite? Conformiq uses *model driven coverage criteria* to answer this question to select a set of test cases to form a good test suite. The coverage goals detailed in Section How to Configure Design Configuration Specific Testing Parameters are used to guide Conformiq Designer to look for certain behaviors from models or to enable certain

behaviors, i.e., to generate test cases that "cover" the coverage goals in the model whether they are related to the constructs in state machines (such as states and transitions) or to the constructs in the action language (such as conditional branching or statements). In Conformiq Designer it is defined that a test case covers a certain coverage goal if execution of the test against the model itself would cause the goal to be exercised.

Test Case Selection

Conformiq Designer uses its capability to simulate the system model symbolically to construct test cases and at the same time it maps the test cases to the different test goals induced by the coverage settings. It then selects from the test cases it has constructed a set that covers all the found test goals using a minimal cost test suite, where the cost of an individual test case is the number of messages in it squared. This ensures that the suite is reasonably small and compact but at the same time the individual test cases remain relatively short, which eases test execution and debugging. In addition to this, Conformiq Designer also prefers to cover all test goals as early as possible, i.e., after as few messages as possible, providing better separation of concerns between test cases.

OSI Methodology Support

In addition to the test selection method described above, Conformiq Designer includes an alternative algorithm for test case selection, namely *OSI Methodology Support* that can be enabled in the *Conformiq Options* page as explained in Section How to Configure Global Testing Parameters. The following are applied when this feature is enabled:

1. The feature enables support for the OSI methodology for organizing test cases as laid out in the ISO 9646-1 standard.
2. All test cases are divided into three sections: *Preamble*, *Body*, and *Postamble*. The *Preamble* section is the "setup" phase that is not considered to be the "actual test", but something that is needed in order to perform the actual test. The *Body* is the "actual test", where a new aspect of the functionality of the system under test is verified. Finally, the *Postamble* section is the "cleanup" phase.

3. All test cases are automatically named. Every test case is named by the name of one of the requirements or structural features that is verified in the *Body* section.
4. Automatic test dependency tracking and the generation of a test case dependency matrix are enabled. The test case dependency matrix shows how the test cases depend on each other. The test cases are ordered in dependency order, so that typically later test cases depend on earlier ones but not vice-versa.

Test sets generated with the "OSI Methodology Support" enabled

- Conform to the OSI methodology for organizing test cases;
- Pinpoint tested requirements more precisely;
- Support dependency-based test execution, so that test cases likely to fail can be bypassed in test execution; and
- Consist of automatically and consistently named test cases, making test set management more straightforward.

Technically every test case can be conceptually divided into "fragments" which correspond to activities that are triggered by (1) input or (2) timeout. *Preamble*, *Body* and *Postamble* always contain only full fragments, i.e., the sections change at fragment boundaries. In every test case, the *Body* is the first fragment that contains a requirement that was not tested in the bodies of the previous test cases.

3.10.2 Perturbation

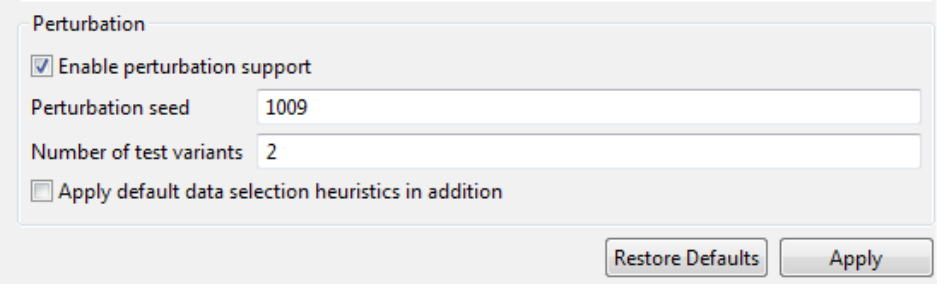
Test Data Selection Using Perturbations

Conformiq Designer designs test cases and test data automatically from a system model. The standard data selection algorithm of the tool operates so that, for example, by default an integer in a message field gets value 0, strings are empty, and so on, if the model does not predict a different value for it.

Perturbation is a Conformiq Designer feature that allows you to generate tests with non-

trivial data distribution. When the perturbation support is enabled, the data values that the tool selects are chosen in a non-trivial fashion so, instead of selecting value 0 for an integer field, the tool may choose to select -7 and your previously empty string may look like "¤)/=)&". The selection is always deterministic, however, so if you clean your test database and regenerate the tests, the tool will generate exactly the same test suite, with the same test cases and with the same test data.

You can turn on the feature by navigating to the Conformiq project properties and selecting "Enable perturbation support". If you wish, you can force the tool to select a different test suite by changing the perturbation seed. As long as the seed is the same, the tests should always remain the same.



Conformiq project properties

Test Case Variants

The feature also supports adding test variants, i.e., you can generate multiple variants of tests, each having different input values. The number of test variants that the tool aims to generate is also configured in the Conformiq project options. If you turn on perturbation and set the number of test variants to let's say 5, the tool aims to generate tests by applying perturbations while it aims to generate 5 variants for each of the tests, each having the same flow and logic, but with different input values. All of the "variant" tests will cover exactly the same model parts as the "non-variant" version; they just have different input data. In effect, if the tool generates 10 test cases and then you set number of variants to 5, you should get out 10 + 5*10 = 60 test cases (in the case that the tool actually manages to find as many variants to

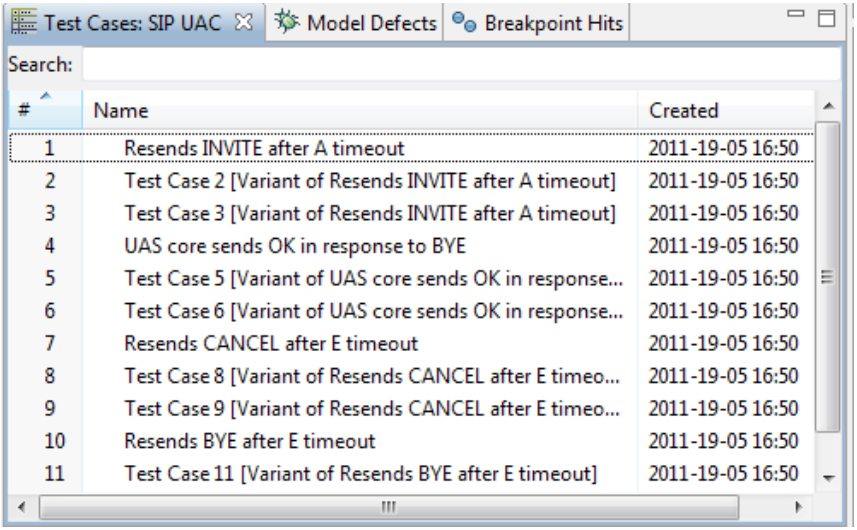
each test).

You can also have variants on top of the tests generated using the default data selection heuristics by turning on the "Apply default data selection in addition" option. In this case, the tool generates the non-variant tests using the default data selection heuristics instead of applying the perturbations, so you get the same tests out as without perturbations plus the variant versions. In the above example, 5 of them for each non-variant test (= 10 non-variant tests, each generated using the default strategy + 50 variant tests, generated by applying perturbations).

Note that it is not guaranteed that the tool can actually generate as many variants as the user has requested for each test. For example, this can't be done if there is no room for data variation at all.

Automatic Naming of Test Case Variants

The generated test case variants are automatically named by the tool with suffix "[Variant of <non variant test case>]", i.e., the variant tests of "Test Case 1" are named as "Test Case 31 [Variant of Test Case 1]", and so on.


Test Cases: SIP UAC
Model Defects
Breakpoint Hits
Search:
Name Created
1 Resends INVITE after A timeout 2011-19-05 16:50
2 Test Case 2 [Variant of Resends INVITE after A timeout] 2011-19-05 16:50
3 Test Case 3 [Variant of Resends INVITE after A timeout] 2011-19-05 16:50
4 UAS core sends OK in response to BYE 2011-19-05 16:50
5 Test Case 5 [Variant of UAS core sends OK in response... 2011-19-05 16:50
6 Test Case 6 [Variant of UAS core sends OK in response... 2011-19-05 16:50
7 Resends CANCEL after E timeout 2011-19-05 16:50
8 Test Case 8 [Variant of Resends CANCEL after E timeo... 2011-19-05 16:50
9 Test Case 9 [Variant of Resends CANCEL after E timeo... 2011-19-05 16:50
10 Resends BYE after E timeout 2011-19-05 16:50
11 Test Case 11 [Variant of Resends BYE after E timeout] 2011-19-05 16:50
Test Case variants in the Test Case List view

3.10.3 Test Generation Time Warnings

The “model inversion” algorithm, which Conformiq Designer uses for test case generation, systematically explores a part of the state space of the model. The state space is basically a collection of all possible behaviors of the model, given an arbitrary environment. For some models even that part of the state space which Conformiq Designer needs to analyze is large, and going through it takes a considerable amount of time: there are model structures that are time consuming for the tool to analyze in which case the tool will warn the user about the problematic structure. The user can use this information to "quicken" test generation in these cases by optimizing the models for test generation speed. Faster test generation speed contributes to a more efficient personal test case design process.

Spinning

Spinning occurs when either the model runs in a never-ending or overly long loop, or when a limitation of the test generation engine causes the test generation algorithm to run endlessly.

One type of spinning that is caused by a limitation of the test generation algorithm is illustrated by the following QML model:

```
system {
    Inbound in : Message;
    Outbound out : Message;
}
record Message { int bound; }
void main()
{
    Message m = (Message) in.receive();
    for (int i = 0; i < m.bound; i++)
    {
        out.send(m);
    }
}
```

In this model there are technically no "infinite" loops because the *for* loop clearly terminates for any particular value of *m.bound*. However, the model does not impose any bound on *m.bound* itself, and therefore the current algorithm tries to analyze the loop with all values of *m.bound*, causing an infinite amount of work. This kind of "breadth spinning" is sometimes detected by Conformiq Designer, and signaled with a warning message such as:

```
Possibly troublesome construct: [source file location]
```

Excessive State Space Branching

There are some modeling constructs that may cause excessive state space branching in which case Conformiq Designer delivers the warning message:

```
Referencing construct that causes substantial state space branching: [source
file location]
```

This warning message is received when an array in the model is referenced with an index that

has no bounds or the bounds are large. For example, consider the following QML model fragment:

```
system {
    Inbound in : Message;
    Outbound out : Message;
}
record Message { int idx; }
void main()
{
    boolean[] array = new boolean[500];
    ...
    Message m = (Message) in.receive();
    require 0 <= m.index && m.index < 500;
    if (array[m.idx])
    {
        ...
    }
    ...
}
```

The above model is "correct" in a sense that it does not reference an array index beyond the bounds of the array (forced by `require` statement. See section Assertion Like Functions for more information about `require` statement). However, the array reference in the model fragment causes excessive state space branching as the tool attempts to analyze the array reference with all the possible values of *m.idx*; the above fragment generates at most 500 different behaviors to be searched, corresponding to 500 different index values.

Using require to Limit the Search Space

If you have programmed in languages like C or C++, you have most likely also tried to optimize your programs for speed. Optimizing test case generation speed is very different. When you optimize a computer program, you try to minimize the execution time of the program given any particular input, but in the case of Conformiq Designer, you want to minimize the number of different executions of the model given “all possible inputs”. The key question is how to limit the search space, which means the portion of the state space that

is examined by Conformiq Designer.

A direct way for limiting the search space in the cases above is to use `require`. To illustrate this, consider the example in Section Spinning, where *bound* is a number that has been received from the environment, a direct way to limit the search space is to limit the value domain of *bound* by applying `require` as follows:

```
 void main()
{
    Message m = (Message) in.receive();
    require m.bound < 10;
    for (int i = 0; i < m.bound; i++)
    {
        out.send(m);
    }
}
```

This model generates at most 10 different behaviors to be searched compared to an infinite amount of possible behaviors as in the first example. Of course, the caveat of this approach is that if for example one of the tests interested in, is to try out what happens after 10 iterations, this test would be missed by the second variant of the code. Therefore require should not be overused when optimizing the model for test generation and Conformiq Designer should be "assisted" only when necessary.

3.10.4 Model Profiler

The **Model Profiler** view can be used to produce and show an execution profile of the model. The main use of Model Profiler is in optimizing the Conformiq models as the Model Profiler can be used to pinpoint problematic constructs in the model, i.e., those model parts on which Conformiq Designer spends most of its time.

Model profiling is disabled by default, but it can be enabled by selecting the **Enable Model Profiling** option in Conformiq project properties. (See Section How to Configure Global Testing Parameters for more information.)

Enabling the model profiler has an impact on the test generation time as Conformiq Designer needs to collect and keep track of several profiled items. The performance degragation is in the area of 20%.

When enabled, the built-in Conformiq Designer Model Profiler collects the following information while generating test cases:

Number of Generated State Space Branches

This figure will give the number of generated state space branches that Conformiq Designer builds while running the test generation algorithm. This number corresponds to the number of different possible choices that can be made in the given part of the model. The bigger this number is, the more complicated the given structure is for Conformiq Designer to handle.

Constraint Solving Time

This figure gives the wall clock time that Conformiq Designer spent in calculating and solving data dependencies and other similar things. The bigger this wall clock time is, the more complicated the data dependencies are and their impact to the analysis of the model grows.

Execution Time

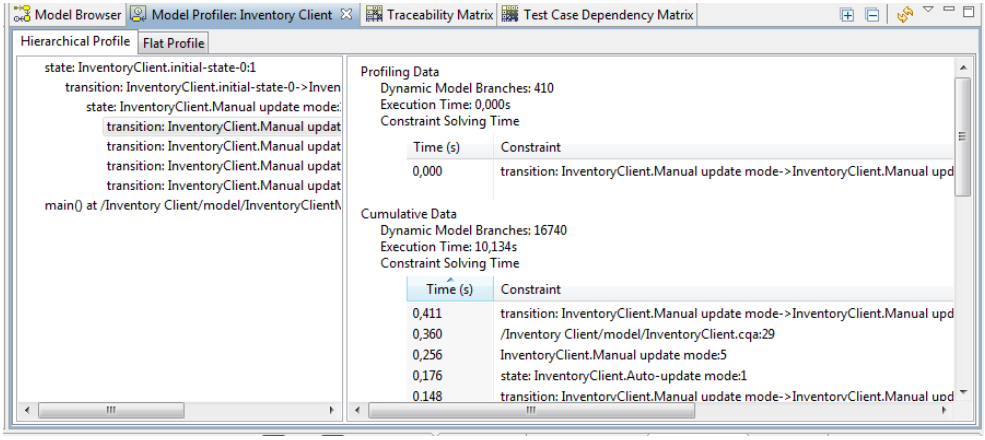
This figure gives the wall clock time that Conformiq Designer spent in executing a given model part.

Two forms of output is available in the Model Profiler view:

Hierarchical View

The Hierarchical View will show all the execution stack traces on the left hand side of the view in a tree view. Each path from the root of this tree view to the leaf of the tree depicts a single execution trace.

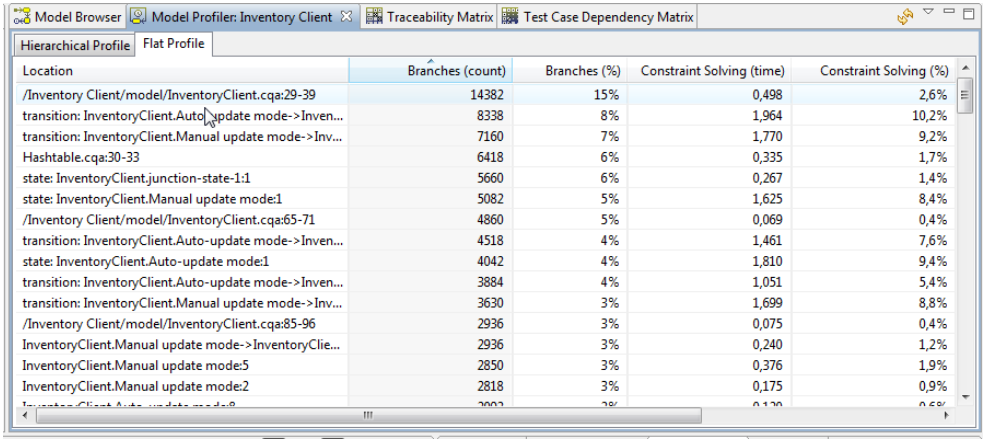
When clicking an item representing a model part on the left hand side of the view, the right hand side of the view is refreshed with profiling information collected for that particular model part, i.e., information about number of created state space branches, constraint solving time, and symbolic execution time. In addition to this information, the right hand side of the view also shows cumulative data from all the execution paths where the selected model part acts as a root.



Hierarchical View of the built-in Model Profiler

Flat Profile

The Flat Profile view shows how much computational resources the analysis of different parts of the model consume. If you simply want to know which model parts are the most problematic for Conformiq Designer, it is stated most concisely in this view.



Location	Branches (count)	Branches (%)	Constraint Solving (time)	Constraint Solving (%)
/Inventory Client/model/InventoryClient.cqa:29-39	14382	15%	0,498	2,6%
transition: InventoryClient.Auto-update mode->Inven...	8338	8%	1,964	10,2%
transition: InventoryClient.Manual update mode->Inv...	7160	7%	1,770	9,2%
Hashtable.cqa:30-33	6418	6%	0,335	1,7%
state: InventoryClient.junction-state-1:1	5660	6%	0,267	1,4%
state: InventoryClient.Manual update mode:1	5082	5%	1,625	8,4%
/Inventory Client/model/InventoryClient.cqa:65-71	4860	5%	0,069	0,4%
transition: InventoryClient.Auto-update mode->Inven...	4518	4%	1,461	7,6%
state: InventoryClient.Auto-update mode:1	4042	4%	1,810	9,4%
transition: InventoryClient.Auto-update mode->Inven...	3884	4%	1,051	5,4%
transition: InventoryClient.Manual update mode->Inv...	3630	3%	1,699	8,8%
/Inventory Client/model/InventoryClient.cqa:85-96	2936	3%	0,075	0,4%
InventoryClient.Manual update mode->InventoryClie...	2936	3%	0,240	1,2%
InventoryClient.Manual update mode:5	2850	3%	0,376	1,9%
InventoryClient.Manual update mode:2	2818	3%	0,175	0,9%

Flat Profiling View of the built-in Model Profiler

Refreshing Profiling Information

Conformiq Designer automatically collects profiling information during the test generation using a built-in model profiler functionality when the model profiler has been explicitly enabled. This information is automatically updated in the Conformiq Eclipse Client user interface when the test generation ends. To see the profiling information before the test generation process ends, click the *Refresh* button on the top of the Model Profiler view. Note that this operation can take some time to complete.

3.10.5 Intelligent Test Case Naming

Intelligent Test Case Naming feature automatically assigns a meaningful name for each test case based on the model parts that the given test case covers.

The automatic test case naming works so that the "best" name for a test case is calculated algorithmically based on requirements, structural checkpoints, and "scenario" and "narrative" tags, which are features introduced in Conformiq Designer 4.4.0.

Scenario and Narrative Tags

The QML language has two constructs that can be used to give meaningful names to the generated test cases:

```
scenario <string expression>;
narrative <string expression>;
```

Here *<string expression>* is a concatenation of string and numeric values, e.g., "foo" + a + i where "foo" is literal, “a” is a string variable and “I” is an integer variable. The evaluation of *<string expression>* cannot have any side effects, therefore for example, function calls are not allowed in *<string expression>*. Both these constructs are "comments" in nature and do not affect test generation.

The difference between "scenario" and "narrative" is in how they are used. All "narrative" fragments are concatenated with automatically corrected punctuation to produce an English narrative of what happens in a test case from the system perspective. The "scenario" fragments are not considered to be sentences and they do not necessarily form a sequential narrative but are considered more of independent labels that together define the present scenario. Also, they should be independent in the sense that even a subset of scenario tags that belongs to a test case makes sense to the user.

For example, in the SIP UAC example context:

```
narrative "user initiates a call.";
scenario "Locally initiated call";
narrative "client sends Invite (100).";
narrative "ringing (180) is received.";
narrative "OK (200) is received.";
narrative "client responds with Ack.";
'scenario "Established call";
...
```

Here the narrative forms a logical sequence, which is rendered as follows below. Note that the narrative necessarily occurs after an input event that triggers it, but it can happen either

before or after an output event, because the user can obviously call either "narrative" or "send" first. Narratives pertaining to output events must therefore be inserted after the actual output event has occurred so that the narrative can be correctly targeted.

User initiates a call. Consequently, client sends Invite (100). Afterwards, ringing (180) is received and then 200 OK (200) is received. At this point, client responds with Ack. Scenario classification: Locally initiated call, Established call.

The string value passed to the *narrative* should start with a lower-case letter in case the first word is a general noun.

Automatic Test Case Naming

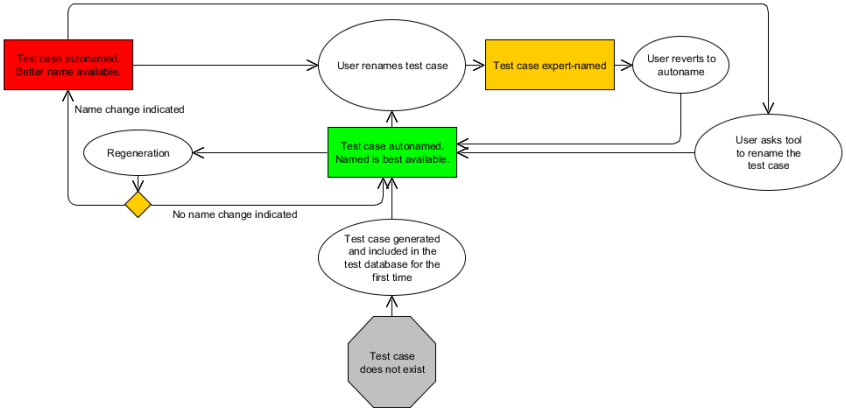
The automatic test case naming works so that the "best" name for a test case is calculated algorithmically based on requirements, structural checkpoints, and "scenario" and "narrative" tags.

Technically, the auto-generated test case name is based on selecting a subset of scenario and narrative fragments, requirement annotations, negative requirement annotations (i.e., requirements not covered in the given test), and structural coverage (checkpoints) tags. For every test case, the subset is a minimum-cost subset of the above coverage points that is still unique within the collection of active test cases. The actual test case name is composed of this subset. If there is none, the auto-generated test name is "Unnamed".

Life Cycle of a Test Case Name

As mentioned before, the "best" name for a test case is calculated algorithmically based on requirements, structural checkpoints, and scenario and narrative tags. When the "best" name changes (there is a change in the model), the original name is kept but it is indicated to the user in the Test Case List view (see Section Test Case List) that the auto-generated name is not the best name available and the user is given option to rename the test cases if desired; this without having to regenerate the whole test database.

The user can change the name of the test case at any time even if it has been automatically generated. Test cases whose names are changed by the user are considered to be "expert named" and will no longer be subject to auto naming, i.e., regardless of changes in the test suite due to test regeneration, the names of expert-named test cases are not even indicated for change. They are indicated to be "manually named" and the user can later revert back to automatically generated naming, if needed.


Test case autonamed. Better name available.
User renames test case
Test case expert-named
User reverts to autoname
Name change indicated
Regeneration
Test case autonamed. Named is best available.
User asks tool to rename the test case
No name change indicated
Test case generated and included in the test database for the first time
Test case does not exist

Life cycle for test case names

See Section Test Case List for more information on how to rename a test case in the Conformiq Eclipse Client user interface and how to revert back to automatically generated test name.

3.11 How to Analyze Test Generation Results

When generating test cases, Conformiq Designer maps the test cases to the different test goals induced by the coverage settings as explained in Section How to Configure Design Configuration Specific Testing Parameters. It then selects from the test cases it has constructed a subset that covers all the found test goals using a minimal cost test suite, where

the cost of an individual test case is the number of messages in it squared. This ensures that the suite is reasonably small and compact but at the same time the individual test cases remain relatively short, which eases test execution and debugging. In addition to this, Conformiq Designer also prefers to cover all test goals as early as possible, i.e., after as few messages as possible, providing better separation of concerns between test cases.

Once the test generation finishes, the Conformiq Eclipse Client user interface shows a number of different views that can be used to analyze the test generation results: in Conformiq Designer the generated tests are visible in the user interface, allowing the user to do detailed analysis of the generated tests. The views that are available for test generation result analysis are the following:

- **Coverage Editor** shows the final status of black-box coverage figures.
- **Test Case List** shows all the generated test cases with the generation date and the name of the test case where users can also rename the test cases.
- **Traceability Matrix View** correlates the coverage options to the test cases that "cover" them.
- **Test Dependency Matrix** shows how the generated test cases depend on each other (see also Section Test Case Selection in Conformiq)
- **Test Case View** shows the interaction between the tester and the system under test.
- **Test Step View** shows detailed information about the messages that are transferred between the tester and system under test in the given test case.
- **Model Browser** provides a read only representation of the model parts in the tool that enables browsing of the model in the user interface and a visual mapping of the generated test cases and encountered model defects.
- **Execution Trace View** links the test case back to the model from which it was generated in a rudimentary way.

3.11.1 Coverage Editor

In addition to selecting the target coverage goals (as explained in Section How to Configure Design Configuration Specific Testing Parameters) **Coverage Editor** can also be used to analyze the status of black-box coverage figures.

While the test generation is running, this view is updated in real time providing the user the means of analyzing the status of the test generation. Once test generation finishes, this view will show the final coverage figures. Coverage status cells can be empty (indicating that the goal was uncovered because it was not targeted), it can contain an icon (indicating that the goal has been covered, or uncovered in spite of being targeted), or it can contain a coverage percentage value in case the status corresponds to a coverage goal group. This percentage value is calculated by the user interface from the intentions (targets) and results (covered targets).

The meanings of different icons in the coverage status cells are given below:

Denotes a covered target goal.

Denotes a target goal that Conformiq Designer failed to cover. Note that while Conformiq Designer is generating test cases, there is no status icon for the given atomic goal. However, if the target goal is still uncovered when the test generation stops, this icon will be shown in the QEC user interface.

Note that when the tests are generated, the coverage setting cells cannot be edited.

If the test generation is aborted by the user, the following happens:

- If the user decides to merge the changes, the Coverage Editor is left in the state that it was (as it was already updated in real time).
- If the user decides to unroll the changes, the Coverage Editor is reverted to the

state before the test generation.

There are several possibilities to filter information in the Coverage Editor using the filtering buttons in the Conformiq Eclipse Client menu bar:

Denotes a filter for unaffected settings. When this filter is enabled, the view will only show those cells that have been edited since the last test generation or that have never been used in test generation (thus each cell is in "edited state" initially, until tests are generated according to its initial setting).

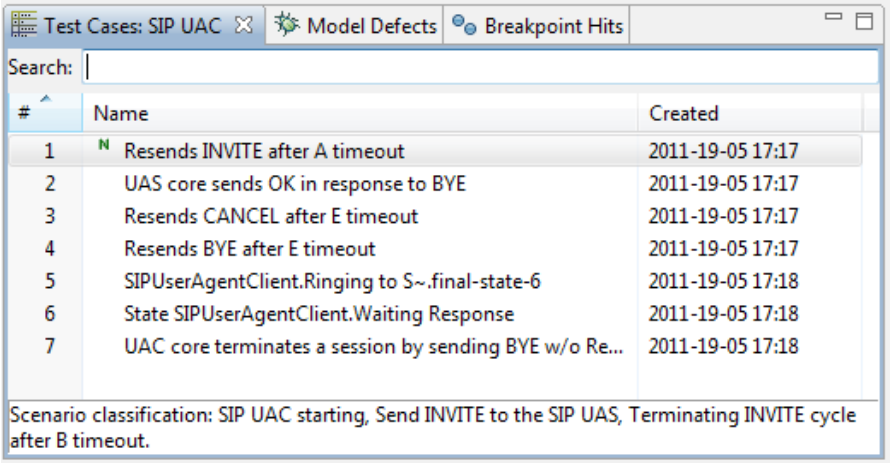
Denotes a filter for "overridden" settings. When this filter is enabled, the view will only show those cells that are not "inherited".

Denotes a filter for uncovered target goals. When this filter is enabled, the view will only show those cells that show a target goal (intention) that Conformiq Designer failed to cover.

3.11.2 Test Case List

The **Test Case List** will show the list of generated test cases once the Conformiq Computation Server has finished with the test generation with the names and creation dates as shown in the Figure.

The Test Case View can be opened by selecting **Window > Show View > Test Case List**.


Test Cases: SIP UAC
Model Defects
Breakpoint Hits
Search:
Name Created
1 N Resends INVITE after A timeout 2011-19-05 17:17
2 UAS core sends OK in response to BYE 2011-19-05 17:17
3 Resends CANCEL after E timeout 2011-19-05 17:17
4 Resends BYE after E timeout 2011-19-05 17:17
5 SIPUserAgentClient.Ringing to S~.final-state-6 2011-19-05 17:18
6 State SIPUserAgentClient.Waiting Response 2011-19-05 17:18
7 UAC core terminates a session by sending BYE w/o Re... 2011-19-05 17:18
Scenario classification: SIP UAC starting, Send INVITE to the SIP UAS, Terminating INVITE cycle after B timeout.

Test Case List

In the Test Case View the test cases can be named and renamed by right clicking a test case in the view and selecting **Rename** from the context menu. The test case names stay consistent over consecutive test generations. Note that at any time you can revert back to the automatically generated test case name by selecting **Revert to auto-generated name** from the context menu. (See Section Intelligent Test Case Naming for more information about automatic test case naming). In case the Conformiq Computation Server manages to generate a *better* name for the test case (due to change in the model), the fact is indicated with a small **N** letter and the left hand side of the test case name (for example *Resends INVITE after A timeout* is such a case). In such a case, you can apply the new name by clicking **Update to auto-generated name** from the context menu.

If the model contains *scenario* or *narrative* tags, the Conformiq Computation Server automatically constructs a description for the test cases (see Section Intelligent Test Case Naming for more information about automatic test case description generation) the test case description will be shown in the bottom of the Test Case list view as shown in the Figure above.

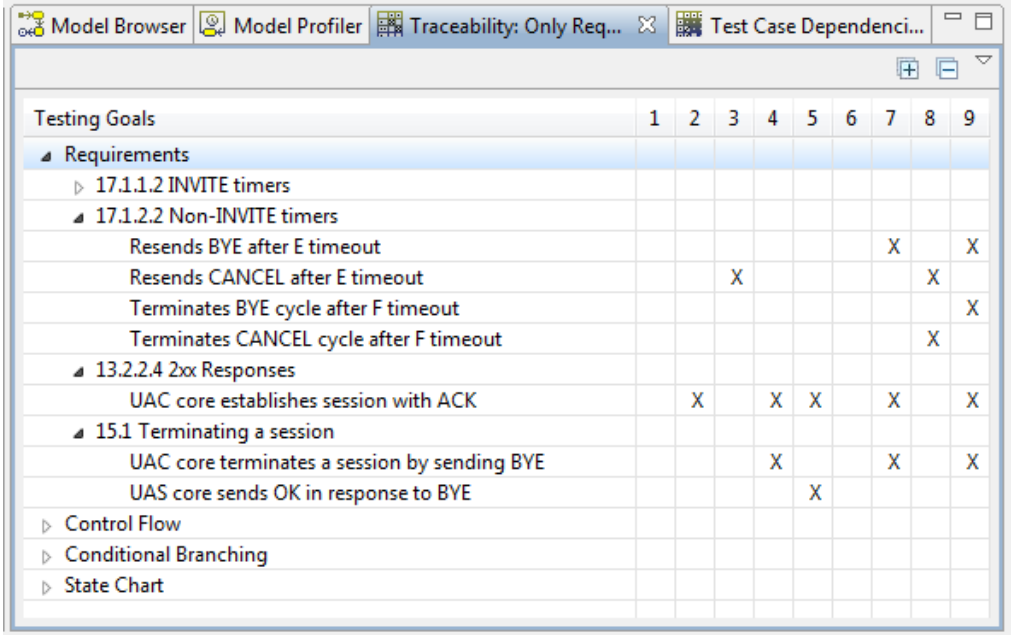
The test cases can be sorted in the view by any of the visible columns. Users can also search

for test cases by name by writing a substring of a test case name in to the text field above the view.

3.11.3 Traceability Matrix View

A **Traceability Matrix** is a table that correlates the coverage goals (structural features and high-level testing requirements) to the matching parts of test cases in many-to-many relationships. The column on the left in the traceability matrix shows the coverage goals and the number of the test cases are placed across the top row. There is a marking cross in the intersecting cell when the coverage goal in the left column is covered in the test case in the top row.

The Traceability Matrix View can be opened by selecting **Window > Show View > Traceability Matrix**.


Model Browser
Model Profiler
Traceability: Only Req...
Test Case Dependenci...
Testing Goals 1 2 3 4 5 6 7 8 9
Requirements
17.1.1.2 INVITE timers
17.1.2.2 Non-INVITE timers
Resends BYE after E timeout X X
Resends CANCEL after E timeout X X
Terminates BYE cycle after F timeout X
Terminates CANCEL cycle after F timeout X
13.2.2.4 2xx Responses
UAC core establishes session with ACK X X X X X X
15.1 Terminating a session
UAC core terminates a session by sending BYE X X X
UAS core sends OK in response to BYE X
Control Flow
Conditional Branching
State Chart

Traceability Matrix

The coverage goal groups can be expanded and collapsed by the user. If a particular test case is active and shown in the matrix, the corresponding column is highlighted.

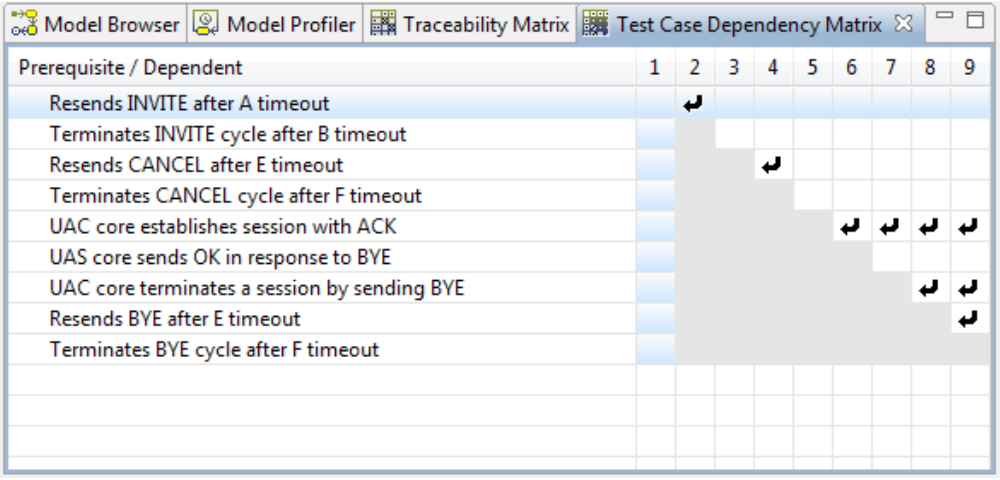
3.11.4 Test Dependency Matrix

The dependencies between test cases are automatically tracked when the test suite is generated using "OSI Methodology Support" (see the Sections How to Configure Global Testing Parameters and Test Case Selection in Conformiq for more information about this option). In addition, Conformiq Designer will automatically generate a **Test Dependency Matrix**, which shows how the test cases depend on each other.

Dependencies between test cases help streamline the test process by ensuring that testing experts focus only on the tests that can be run. This means that when *Test Case B* depends

upon *Test Case A*, *Test Case B* cannot be executed until *Test Case A* passes, because if the execution of *Test Case A* fails, *Test Case B* will fail as well so it makes no sense for the test expert to try to execute *Test Case B* before *Test Case A* can be re-executed successfully.

A test case named in the leftmost cell of a row in the **Test Dependency Matrix** is a prerequisite for all test cases marked in that row of the matrix. Conversely, the test cases on which a given test case depends can be seen in the column having the number of the test case in its topmost cell. For example, in the figure below, the test case *#1: requirement: 17.1.1.2 INVITE timers/Resends INVITE after A timeout* is a prerequisite for test case *#6: requirement: 17.1.1.2 INVITE timers/Terminates INVITE cycle after B timeout*, and conversely, test case #6 is dependent on test case #1. This means that if the execution of test case *#1: requirement: 17.1.1.2 INVITE timers/Resends INVITE after A timeout* fails, we know for sure that also the execution of test case *#6: requirement: 17.1.1.2 INVITE timers/Terminates INVITE cycle after B timeout* will fail, and therefore it makes no sense to execute it before the prerequisite test case passes.

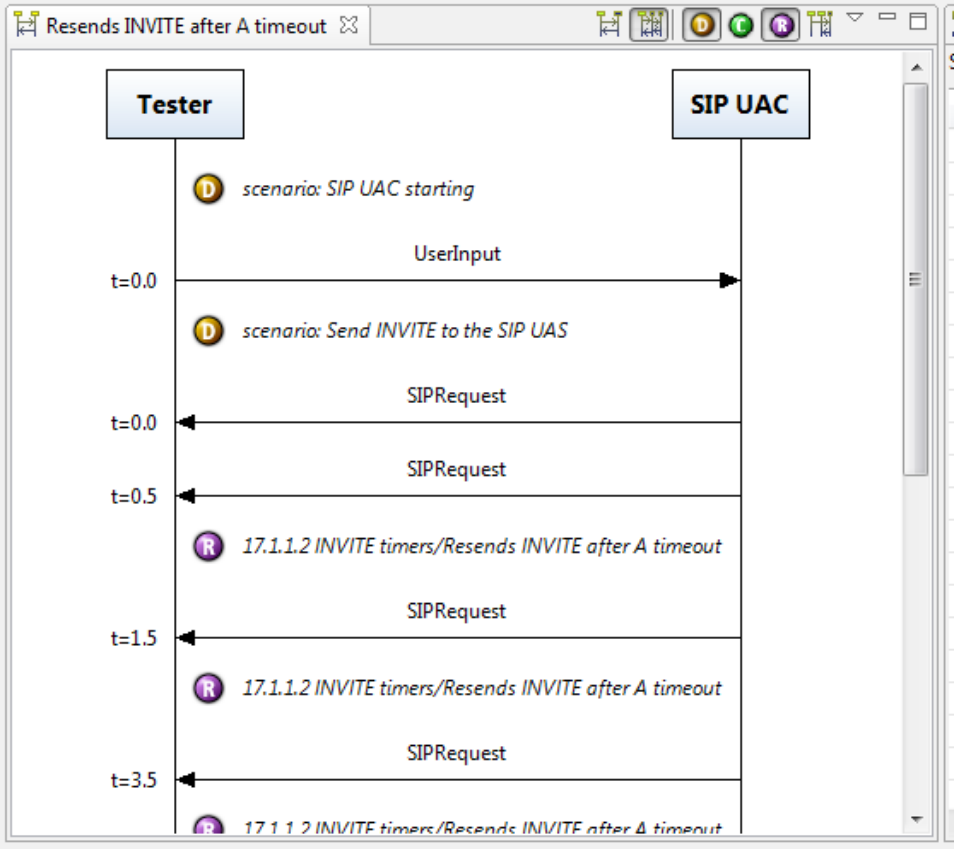

Model Browser
Model Profiler
Traceability Matrix
Test Case Dependency Matrix
Prerequisite / Dependent
1 2 3 4 5 6 7 8 9
Resends INVITE after A timeout
Terminates INVITE cycle after B timeout
Resends CANCEL after E timeout
Terminates CANCEL cycle after F timeout
UAC core establishes session with ACK
UAS core sends OK in response to BYE
UAC core terminates a session by sending BYE
Resends BYE after E timeout
Terminates BYE cycle after F timeout

Test Case Dependency Matrix showing dependencies between test cases generated from the SIP UAC example model that is part of the Conformiq distribution

3.11.5 Test Case View

The **Test Case View** shows the flow of logic within the test case, i.e., the interaction between the tester and the system under test (Tester and SUT in the view). The tester and the system under test are represented as parallel vertical lines ("lifelines") representing the life span of the object during the test scenario. The message take-overs between them are represented with horizontal arrows augmented with the name of the message being transferred, the name of the port, and the exact time stamp at which the message is transferred.

The Test Case View can be opened by selecting **Window > Show View > Test Case View**.



Message Sequence Chart of a test case

In order to also see how internal model threads interact, you can open the extended Test Case View by clicking **Show all messages** on top of the view. The extended view will show the tester as the leftmost lifeline and each named internal thread as a separate lifeline to the right from the tester lifeline. The extended view will also show all the internal message take-overs between the internal threads.

To get back to the basic view, i.e., to see only the interaction between the tester and the

SUT, click **Show external messages only** on top of the view.

To show the communication interfaces on the Tester side, click **Show/hide tester ports**.

There are also 3 filters in the top of the view for showing and hiding coverage goals that are covered by the test case:

Show/hide covered requirements is used to filter the covered requirements.

Show/hide covered structural features is used to filter the covered structural features.

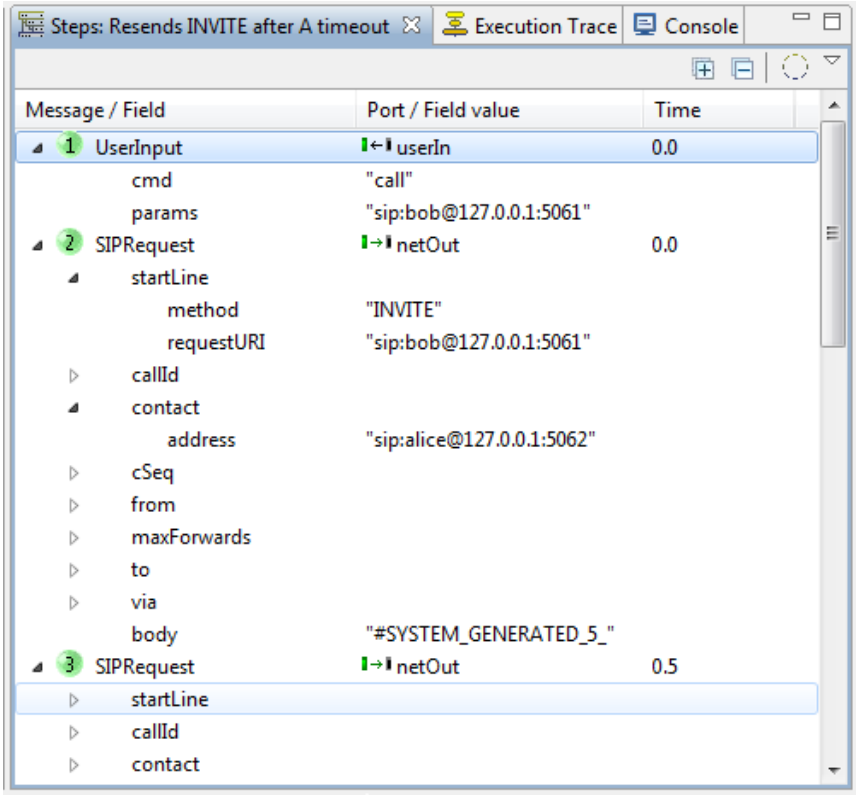
Show/hide debug trace is used to filter the covered scenario and narrative tags in addition to debug trace tags (via calls to predefined `trace()` function in QML).

3.11.6 Test Step View

The **Test Case View** shows the interaction between the tester and the SUT with name of the messages that are transfered. The **Test Step View** shows more detailed information about the message content. The following information can be obtained from this view:

- The number of the test step. The first test step in the test case will always have the number 1.
- The name of the type of the message being transferred between objects.
- The name of the port to which the message was sent.
- The time stamp of the test step, i.e., at what time the message was transferred.
- The content of the structural message with the field name and field value. See Section Record Types for more information about structural messages.

The Test Step View can be opened by selecting **Window > Show View > Test Step View**.



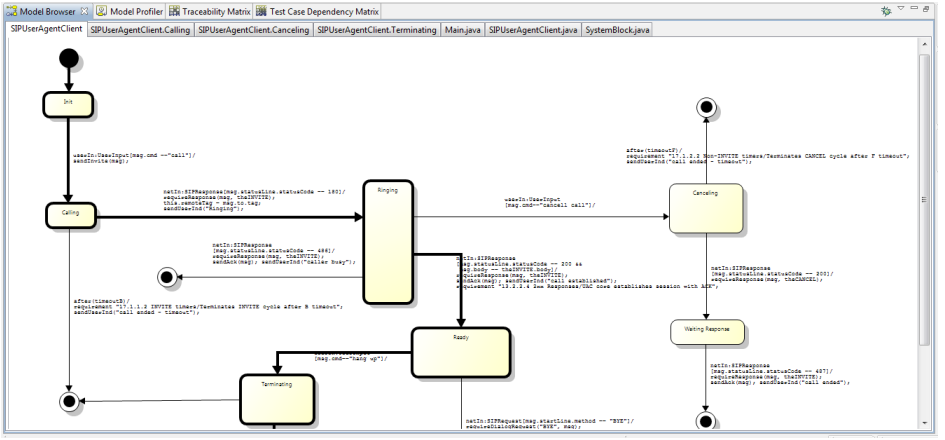
Test Step View showing content of test steps

3.11.7 Model Browser

The **Model Browser** view shows both graphical and textual parts of the loaded model in a read only mode.

Once a model has been successfully loaded, the Model Browser is refreshed to show the structure of the loaded model. In the Model Browser view there is a tab for each state

machine in the model and one tab for each textual file in the model. The label of the tab is the name of the corresponding state machine or the textual file.



Model Browser showing the *SIPClient* state machine of the SIP UAC example model that comes with Conformiq distribution

Examining the Location of Coverage Options

As mentioned in Section Coverage Editor, the Coverage Editor is used to set coverage settings for the test generation. In order to see which part of the model a given coverage goal corresponds to, you can click items in the Coverage Editor which then triggers the Model Browser to highlight the corresponding model part using a dashed box around the given model structure.

Examining Uncovered Target Coverage Goals

After a model has been successfully loaded and test generation has been completed, the Model Browser will automatically highlight in red those model parts that Conformiq Designer failed to cover in the generated test suite. This information can be then used in reasoning whether the target goals were left uncovered due to a modeling error, too low search depth, etc.

Examining Execution Traces

The Model Browser can also be used to examine and analyze the execution paths of test cases in the model that would be seen if the test case were executed or simulated against the model itself. This information helps users to understand the relation between the model and the generated test cases.

The highlighting in the Model Browser works as follows:

- When a test case is selected for example in Test Case List, the Model Browser will highlight the execution of the given test case in the Browser. If there are multiple model threads active in the given test case, the execution of all the threads is highlighted in the Model Browser.
- When a model thread is selected in the Test Case view, only the execution of the corresponding model thread will be highlighted. The selection of the model thread in Test Case view is carried out by clicking the lifeline of the model thread in the view.
- When an external test step (a message take-over between the Tester and the SUT) is selected in the Test Case view or in the Test Step view, the Model Browser will highlight the full execution path of the model thread that handles the given external test step. In addition, the Model Browser will also highlight separately the part of the model that the given test step covers. This way, the user will see the parts of the model that the given model thread covers in the test case in addition to the model parts that the given test case covers.
- The arrow indicating an internal test step (a message take-over between two model threads) is split in two from the middle of the arrow. If you select the sending part of the arrow in the Test Case view, the Model Browser will highlight the execution path of the sender thread and the selected test step in a similar fashion as when an external test step is selected. Correspondingly, the execution path of the receiver thread is highlighted if the receiving part of the arrow is selected. When an internal test step is selected in the Test Step view, the execution path of the sender thread is

highlighted.

Zooming the Model in the Model Browser

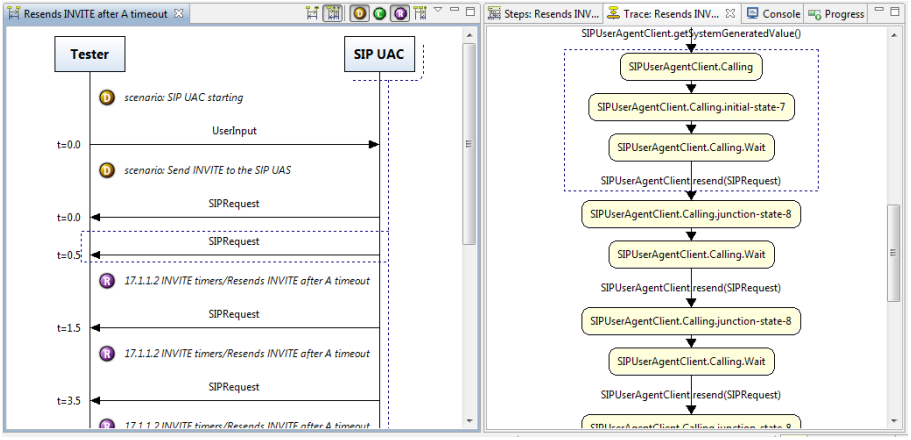
If the model part is too big to fit in the window of the Model Browser, the model can be zoomed in and out using **CTRL +** and **CTRL -** keyboard keys in order to, for example, see the full state machine in the view at once. The zoom can be reset to "1:1" by using **CTRL 0**.

3.11.8 Execution Trace View

The **Execution Trace View** shows the execution trace of the test case in the model, i.e., the execution path in the model that would be seen if the test case were executed against the model itself. The information in the view is shown graphically so that each state machine level state is represented as a rounded box with the name of the state inside, the state machine level transitions (i.e., the transfer of control from one state machine level state to another) are represented as arrows between the states, and action language level method invocations are represented as text.

In essence, the Execution Trace View provides a rudimentary way to link the generated tests back to the model from which the tests were generated by showing the execution flow in the model.

The Execution Trace View can be opened by selecting **Window > Show View > Execution Trace View**.



Execution Trace View

3.11.9 Analyzing Model Defects

The design model of a system documents the desired functionality of the system; model driven testing turns these functional requirements into valuable testing assets. It is correct to see a system model as a golden reference implementation of the system. However, since system models are human made, they may contain errors; They could for example, when simulated, cause a null pointer reference and crash, and concurrent models can deadlock.

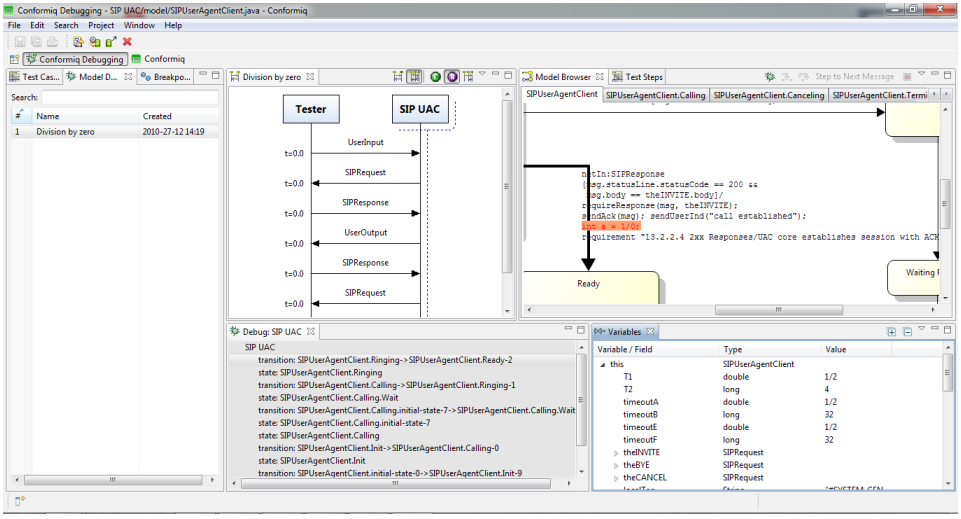
While performing the test generation, Conformiq Designer also verifies that the model is internally consistent, i.e., the tool will check for the absence of internal computation errors (such as division by zero) while it analyzes the model. The Conformiq model debugger is an infrastructure that allows the user to analyze various issues in the model and get a better understanding of the automatically designed and generated test cases. The model debugger is used to analyze problems that are encountered during the test generation.

One of the most important uses of the model debugger is its application in the analysis of various issues in the user defined model, more precisely:

- Model crashes like assertion failures, division by zero, null pointer reference etc.

- Model deadlocks
- Non deterministic test cases

The model debugger framework provides the capability to analyze in detail the situation in which the problem occurs (i.e. the state of the execution of the model) and it allows for the means of analyzing the execution trace that leads to the given problem via a single stepping model debugger. The model debugging in Conformiq Designer is organized so that the model defects (amongst test cases) are analyzed in a distinct new perspective called **Conformiq Debugging**. Conformiq Designer will automatically switch to this perspective when the user initiates model debugging tasks. A distinct perspective helps to keep the UI clear and understandable by providing only the views that are required for running the model debugger.



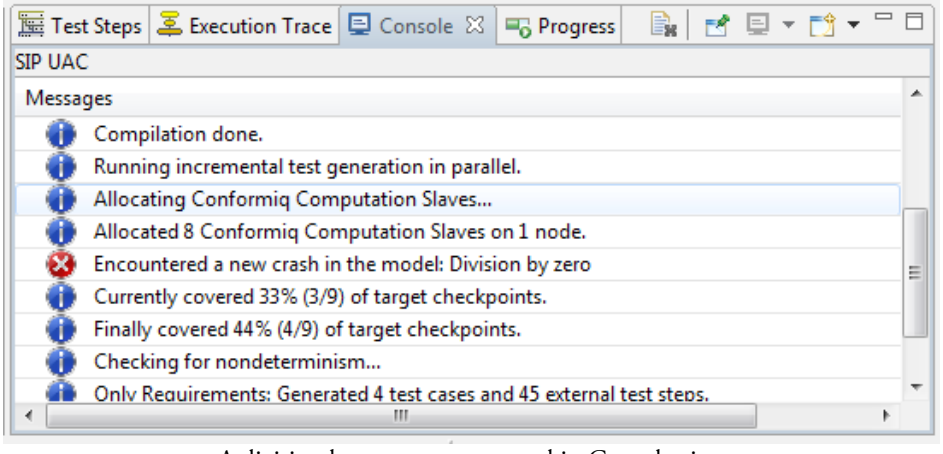
Conformiq Debugging perspective

General Work Flow

This section briefly describes a normative work flow or a typical use case of the model

debugger and the steps involved in operation with the debugger.

- The user loads the model and starts the test generation.
- If the tool encounters a model defect, the user is notified about the encountered problem which is summarized in the Console view of the Conformiq Eclipse Client user interface. The encountered problem is also placed into a view called "Model Defects" next to a list of generated test cases (which are placed in the "Test Cases" view). The summary of the problem presented in the console view is one line encapsulating the type of the problem.
    - The user can also set test generation time breakpoints via the Model Browser which can be used when analyzing reachability issues where the user expects that after a certain model part is executed, the tool truncates the execution. Every time a breakpoint is hit during test generation, the corresponding trace (up to the breakpoint) is added in a "Breakpoint Hits" view, that is similar to the Test Cases and Model Defects views and behaves similarly.

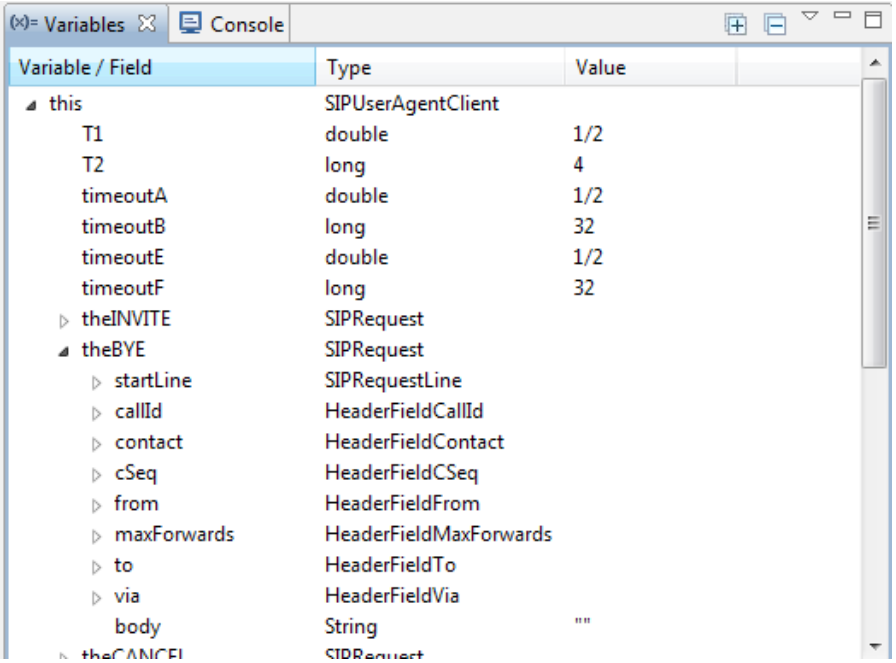

Test Steps
Execution Trace
Console
Progress
SIP UAC
Messages
Compilation done.
Running incremental test generation in parallel.
Allocating Conformiq Computation Slaves...
Allocated 8 Conformiq Computation Slaves on 1 node.
Encountered a new crash in the model: Division by zero
Currently covered 33% (3/9) of target checkpoints.
Finally covered 44% (4/9) of target checkpoints.
Checking for nondeterminism...
Only Requirements: Generated 4 test cases and 45 external test steps.

A division by zero error reported in Console view

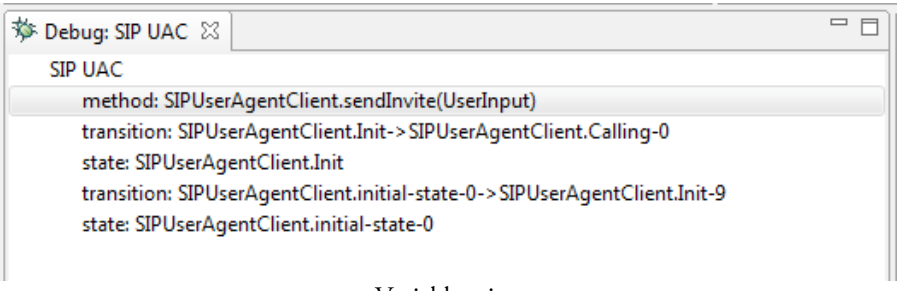
- When the user clicks the problem summary in the Console view or the model defect in the "Model Defects" tab, Conformiq Designer will prompt the user that a

switch to a distinct perspective, namely Conformiq Debugging perspective, will be carried out. This distinct perspective contains a subset of the views available in the "Conformiq" perspective and is depicted in the figure below. The following information is available in the "Conformiq Debugging" perspective:

- MSC view (or "Test Case View") will show the I/O trace leading to the model defect (this is the "main" view in the model debugging perspective as the high level understanding of the actual model defect is expected to be best understood via the I/O trace),
- Test Step view shows the detailed data content of the given I/O trace, Model Browser highlights the execution path on a model level to the defect,
- "Debug" view shows the execution stack traces of all the *alive* model level threads (that have been given a name by the user as detailed in Section Threads and Communication) in a thread view, and
- "Variables" view will show the current environment (i.e. the current variables and their values).



Debug view



Variables view

- In order to perform a more detailed analysis of the execution that led to the problem, the user can single step the execution on the model level via "Execution Trace Analyzer". While single stepping the execution, the user is presented with the

information about the current state of each variable in the current execution environment utilizing the "Debug" and "Variable" views.

- The user switches back to the "Conformiq" perspective, fixes the model, reloads the updated model, and reruns the test generation. At the beginning of the test generation, the tool checks whether the existing problems can be reproduced with the updated model. The problems that are not fixed are once again reported to the user so that the user can perform further analysis on them. If the model updates introduce new issues, those are reported as mentioned above.

Managing Model Defects

All the model defects encountered during the test generation process are collected in to a model defect collection. The content of this collection is available in the user interface in a list view called "Model Defects". This view will be positioned next to the "Test Cases" list in the UI. Model defects are also internally stored in the Conformiq project database.

The content of the model defect collection is automatically maintained as follows:

- When a model defect is encountered for the first time during the test generation process, it will be placed into the collection and stored internally in a database so that if user exits the tool, the model defects are not lost.
- When the user regenerates the test cases, the Designer will first check whether the known defects can be reproduced from the model by running the known model defects against the model. This happens via the same mechanism as asset analysis, so in essence the tool will analyze whether the model defect is still valid.
- Those model defects that are now "invalid" (i.e. we cannot produce this defect from the model anymore) are automatically removed from the model defect collection while those that are "valid" will be kept in the collection. This way the user is made aware about the status of the model after updates.
- The list of model defects will empty only when there are no existing model defects and the tool will not encounter new defects during the test generation.

Note that you can also delete all the model defects from the database by clicking "Delete Test Cases".

Model Defects

In general, when Conformiq Designer finds that the model crashes during simulation it does not stop test generation. Conformiq Designer reports the error and then continues to analyze other branches of the model where the same problem may or may not manifest.

Model Crash (assertion failures, null pointer references, division by zero)

Null Pointer References

Null pointer references (trying to access an object via reference whose actual value is null) are indicated by an error message such as:

```
“[source file location]”: “Failed assertion: |’Null pointer reference|”
```

Division by Zero

The *division by zero* runtime error occurs when during a simulation of the model an arithmetic division takes place with the divisor being zero. For example, consider the following QML model:

```
system {
    Inbound in : Message;
    Outbound out : Message;
}
record Message { int q; }
void main()
{
    Messafe r = (Message) in.receive();
    int x = 1 / (3 + r.q);
    out.send(r);
}
```

If you try to generate tests from this model, you get the following error message during test generation

```
“[source file location]”: “Division by zero”
```

Note that Conformiq Designer does some active work in trying to spot problems in the model. For example, here Conformiq Designer tries to actively construct an input message that would cause the division by zero to occur. Basically, Conformiq Designer makes divisions by zero, null pointer references and similar abnormal conditions extra testing goals that it tries to fulfill during test generation.

Failing Assertions

You can define assertions yourself in the model (refer to Section Assertion Like Functions on how to define assertions in QML using the `assert` statement). The execution of an assert statement whose argument evaluates as false is considered an error in the same way as a division by zero or null pointer reference is an error. It is reported with a message like:

```
"[source file location]": "Failed assertion: '|User defined assertion in QML
model: [source file location]|”
```

Assertions are typically used for internal consistency enforcement. For example:

```
int y = x * x;
assert y >= 0; /* The square cannot be negative */
```

Information Presented Upon Encountering a Model Crash

The model debugger provides the following pieces of information upon encountering a model crash:

- Cause of the model crash which will be presented in the Console log. This will also be the name of the given model defect that will be placed in the "Model Defects" view.
- Syntactic location of the model crash.
- Name of the thread that caused the model to crash. This information is presented in the header of "Debug" view when the given defect is selected in the UI.
- I/O trace from the beginning of the model execution to the encountered issue including all external and internal test steps plus the checkpoints covered during the execution. This information will be presented in the MSC view when the given defect is selected in the UI.
- Execution stack traces of all the *alive* threads while the thread that caused the model to crash is highlighted. This information is presented in the "Debug" view when the given defect is selected in the UI. When a thread is selected in the "Debug" view, the execution path of that thread will be highlighted in the Model Browser
- The current status of the system including all the current variables and their values (This piece of information is very valuable to the user when encountering model crashes and with this information, the user can most likely solve a number of problems). This information is presented in the "Variables" view when the given defect is selected in the UI.

Model deadlock

A *deadlock* occurs when one or more threads in a model are provably in a situation where they will wait forever for data that will never arrive. The following simple QML model demonstrates a deadlock:

```
system {
    Inbound in : Message;
    Outbound out : Message;
}
record Message { }
void main()
{
    CQPort p = new CQPort();
    p.receive();
}
```

In this model, the main thread deadlocks, triggering an error message like:

```
"[source file location]": "Thread main is in deadlock."
```

The main thread is in a deadlock because it is waiting for a message from port p without a timeout, but there is (obviously) no one who could write to port p as it is only the main thread itself that has a reference to the port. Therefore the main thread is provably in a never-ending wait: a deadlock.

It is possible to create models where multiple threads enter in a mutual deadlock where each of the threads is waiting for a message from another, or is trying to send a message to another thread that is not ready to receive it.

The model debugger provides the following pieces of information upon encountering a model deadlock:

- Names of the threads that are in deadlock. This will also be the name of the model defect. This information is presented in the "Debug" view when the given defect is selected in the UI.

- The operation that an individual thread is performing (write to an internal interface, read from an internal interface, access to mutex or similar). This information is presented in the MSC view when the given defect is selected in the UI.
- I/O trace will be presented as in 5.1.
- Execution stack trace of each deadlocked thread. This information will be presented as in 5.1.
- The current status of the system including all the current variables and their values. This information will be presented as in 5.1.

Non Deterministic Test Case

- I/O trace will be presented as in 5.1.
- A list of (all) the possible continuations. One continuation represents one possible execution after a certain action. Each continuation therefore contains the relevant information for inferring the actions including
  - I/O trace,
  - execution stack traces of all the *alive* model level threads including the content of each stack frame (variables)

Breakpoints

Before the test generation starts, the user can set breakpoints to model in the Model Browser view. Every time a breakpoint is hit during test generation, the corresponding trace (up to the breakpoint) is added in a "Breakpoint Hits" view, that is similar to Test Cases and Model Defects views and behaves similarly. An icon is used to indicate a breakpoint in the Model Browser.

Breakpoints are set via the model browser so that user right clicks an item in the model browser which opens a context menu containing an item "Set Breakpoint". Breakpoints can

be removed by clicking a *breakpoint symbol* in the model browser and selecting "Remove Breakpoint" from the context menu.

Breakpoint Trace

A "breakpoint trace" in the Breakpoint Hits view has the following properties

- Automatically generated identifier that is used to identify the breakpoint trace globally
- I/O trace from the beginning of the model execution to the encountered breakpoint including all external and internal test steps plus the checkpoints covered during the execution. This information will be presented in the MSC view when the given breakpoint trace is selected in the UI.
- Execution stack traces of all the *alive* threads while the thread that hit the breakpoint is highlighted. This information is presented in the "Debug" view when the given trace is selected in the UI. When a thread is selected in the "Debug" view, the execution path of that thread will be highlighted in the Model Browser
- The current status of the system including all the current variables and their values. This information is presented in the "Variables" view when the given defect is selected in the UI.

The breakpoint traces are not persistent i.e. their lifecycle does not expand beyond single test generation run. Therefore, the content of Breakpoint Hits view is automatically cleaned when the model is reloaded, test generation is restarted, or the project is closed.

Lifecycle of Breakpoints

The breakpoints are persistent and stored in to the Conformiq project. Breakpoints are always deleted explicitly by the user through the Model Browser. In practice, the user sets one or more breakpoints before the test generation starts via Model Browser. Each breakpoint is indicated by an icon in the Model Browser. While test generation is running, the tool records the traces leading to the breakpoints encountered. While the test generation

is not running, the user can delete breakpoints by clicking a breakpoint in the Model Browser and pressing the DELETE key or selecting "Remove Breakpoint" from the context menu.

Single Stepping Debugger

The single stepping debugger is used to analyze model execution of known traces that are generated by the tool; not only the model defect i.e. single stepping debugger enables the single- stepping of

- model defects
  - each encountered problem can be further analyzed via a single stepping model debugger that allows the user to single step the execution of the execution trace leading to the problem at hand allowing a detailed analysis of the issue
- breakpoint hits
  - the single stepping debugger can be used to analyze execution traces to user defined "breakpoints" in the model. These breakpoints are set via the model browser before the test generation.
- valid test cases
  - in order to provide a better understanding of the generated test cases, each generated test case can be further analyzed via the single stepping debugger
- redundant test cases
- invalid test cases (up to failure, i.e. invalid output or require conflict)

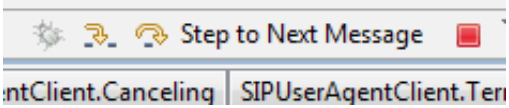
It provides the means of single stepping the known execution trace step by step allowing the user to perform a detailed analysis of the given execution trace.

In practice, the single stepping debugger is available only in the "Conformiq Debugging" perspective and it is controlled via "Model Browser" i.e. all the actions for setting breakpoints, single stepping, etc. are enabled directly in the Model Browser. The actions for

running single stepper are enabled only in the "Conformiq Debugging" perspective.

The single stepping is performed on a QML language statement level i.e. stepping causes execution to advance to the next statement. The single stepping can be extended in the future to support backward stepping.

For single stepping, the "Model Browser" is extended with the following controls:



Controls in the single stepping debugger

- **Debug** action will start the single stepping process. It is the only active action when the single stepping process has not been started. Debug action will take the execution to the first statement covered by the given trace. Once the single stepping process is initiated via Debug, this action will be disabled until the user performs a Stop action or we reach the end of the trace being single stepped.
- **Stop** action will abort the single stepping process. This action is only enabled when the user has started the single stepping process via the Debug action.
- The single stepping debugger does provide the means of running the execution directly to a given model location without having the need to single step to the location. This action is triggered via the Model Browser by the user clicking a model part and selecting **Run to Here** from the context menu
  - If the single stepping is not already running on the trace (and there is no other single stepping process ongoing), triggering the action will start the process of single stepping and takes the execution directly to the given point in the model
  - If the single stepping is already running, triggering the action will take the process of single stepping from the current breakpoint and takes the execution directly to the given point in the model

Note that Run to Here can be used to jump to arbitrary locations of the trace being analyzed, therefore allowing the user to also step backwards in the trace.

In Conformiq Designer 4.4.1 the **Run to Here** action has also been added to the Execution Trace View (which shows the execution trace of the test case in the model, i.e., the execution path in the model that would be seen if the test case were executed against the model itself). This gives the user more fine grained control of the location in the execution trace to which the single stepping debugger should be taken in to. Like in the *Model Browser*, this action is triggered by clicking a location in the execution trace and selecting **Run to Here** from the context menu

- **Step Into** action will perform model level single stepping (i.e. it will step to the next statement or a state chart state or transition).
- **Step Over** action will perform the same operation as *Step Into* except that when it reaches a call for another function, it will not step into the function, but instead the stepping will be brought to the next statement in the current function.
- **Step to the Next Message** action will take the execution to the statement preceding the next I/O action in the trace being analyzed

The following keyboard bindings are attached to the above actions:

Key Binding	*Action*
F5	Step Into
F6	Step Over
F8	Step to Next Message

When the single stepping is running on an execution trace, the user cannot start an analysis of another execution trace and return back to analysis of the original trace. If the user selects another test case / model defect, Designer will prompt a message to the user detailing that the single stepping process will be aborted if the user wishes to continue. Also, the single stepping debugger will be aborted if the user switches back to "Conformiq" perspective in

which case the Designer will notify the user as well.

The execution of the trace is highlighted in the model browser in real time so the user can see at all times what part of the model the single stepping has covered so far, as well as what part of the model is still to be covered by the execution trace.

The variable values of the current environment are visible in a complementary view called "Variables". This view is divided in to 3 columns "Variable / Field", "Type", and "Value" and it shows the current environment during the process of single stepping:

- Variable / Field will show the name of the variable
- Type will show the type of variable
- Value will show the current value of the variable

The variables in the *Variables* view can be sorted alphabetically to ascending and descending order based on the variable name and variable type which eases the task of finding an interesting variable especially when the number of variables grows.

The current execution stacks of each executing model thread are visible in the single stepping debugger at all times. This view will show the evolution of executions stacks as the user single steps the execution.

3.12 How to Export Test Cases

There are software processes wherein it is beneficial to generate separate test scripts that can be stored in version control systems, maybe distributed, and executed independently afterwards. To meet this need, Conformiq provides the means for generating test scripts from system models where test cases are derived automatically from a functional design model and can be executed against a real system.

Test scripts can be generated by scripting backends that are connected to Conformiq using a well-defined API. These scripters can be created by the organization that employs Conformiq for testing, or they can be outsourced or, in some cases, bought as off-the-shelf software components.

In Conformiq the scripting backends are Java archives and Java is the programming language used to implement scripting backends.

The Conformiq distribution is shipped with a number of scripting back-ends.

- An HTML script backend for generating browsable HTML documents.
- A TTCN-3 script backend for generating test script in TTCN-3 which enables employment of model driven testing in a TTCN-3 environment.
- A TCL script backend for generating test scripts in TCL which enables employment of model driven testing in a TCL environment.
- A Perl script backend for generating test scripts in Perl which enables employment of model driven testing in a Perl environment.

Each test design configuration can contain more than one scripting backends.

The **New Scripting Backend Wizard** is used to add scripting backends to test design configurations. With the wizard, user can add scripting backends from multiple different sources to the given test design configuration, for example, from the current Eclipse workspace, from local file system, or from *external scripting backend warehouse*. User can also update scripting backends (if new version is available) downloaded previously from external source using scripting backend wizards.

The scripting backends from different sources are added to test design configurations as follows:

1. Select a test design configuration from the Project Explorer to which the scripter is added.
2. Select **New > Scripting Backend** from the pop-up menu. This will open the **New Scripting Backend Configuration** wizard.

By default, all available scripting backends in the Conformiq Designer Eclipse workspace are listed by the wizard in *Designer Workspace*, including scripting backends that were

downloaded previously (the Conformiq Designer workspace location is *<workspace>/.metadata/.plugins/com.conformiq.qtronic.client/*).

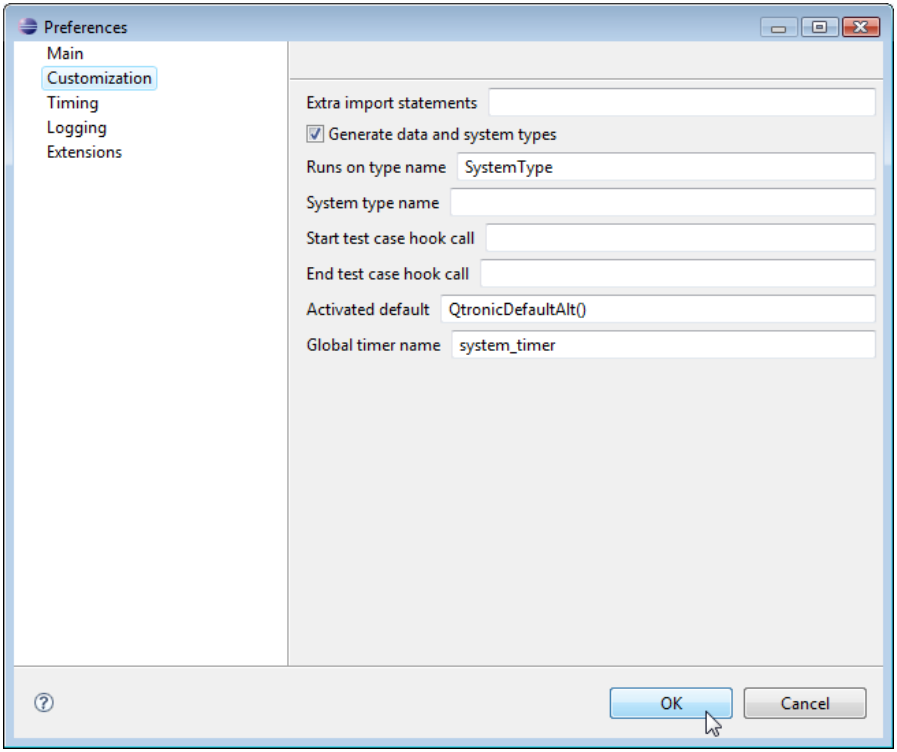
User can click **Browse** button to locate other scripting backends from local file system. By default, **Browse** directs user to the installation directory where user can easily access scripting backends available.

User can click **Show external** to locate scripting backends from *Conformiq scripting backend warehouse*.

With **New Scripting Backend Wizard** it is possible to include more than one scripting backend to the given test design configuration.

The next step is to configure the selected scripting backend. This is carried out as follows:

1. Select the scripting backend from the Project Explorer you wish to configure.
2. Select **Properties** from the pop-up menu. This will open the **Properties** wizard where you will see all the scripter specific configuration options.
3. Configure the scripter.
4. Once the scripter has been properly configured, click **OK**.



Configuration for TTCN scripter

Note that the configuration is scripting backend specific. Section How to Use Script Backends Shipped with Conformiq details how to configure scripting backends shipped with Conformiq.

The Conformiq generated test cases can then be exported by clicking **Render Test Cases**.

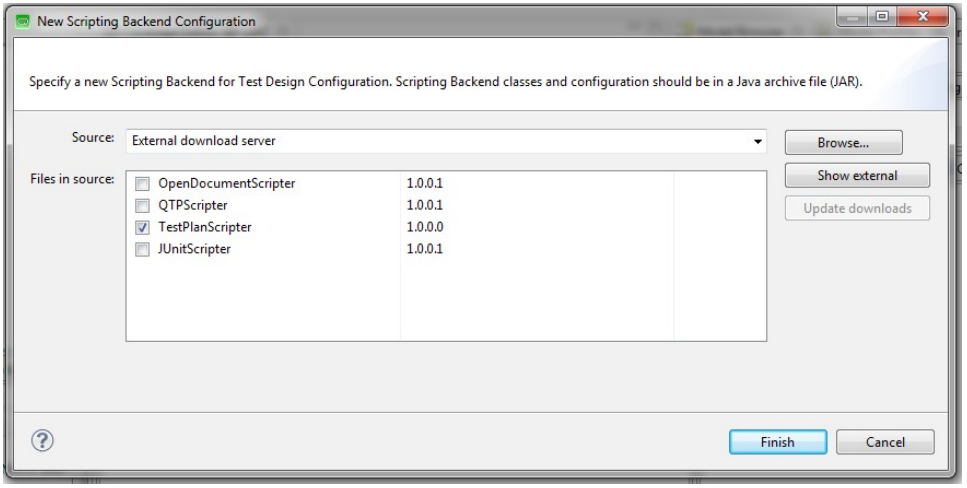
Note that selected scripting backends can be enabled and disabled. By default, all the scripting backends are enabled. In order to disable a scripting backend, select

the scripting backend from the Project Explorer view, and select **Disable** from the pop-up menu. The scripter can be re-enabled similarly.

3.12.1 How to Use Scripters from Scripter Warehouse

Conformiq external scripter warehouse feature provides facility to download and use new scripting backends from online Conformiq repository. It also provides update notification if new version of scripting backends are available during test case rendering process. Using this feature, user can access all available backends from online repository and add specific backend based on the needs.

In order to get access to external scripting backend warehouse, the Conformiq Eclipse Client needs to be installed on a machine that has Internet connection.



The scripting backends are downloaded from the external scripter warehouse via **Scripting Backend** wizard

The scripting backends from external scripting backend warehouse are added to test design configurations as follows:

1. Select a test design configuration from the Project Explorer to which the scripter is added.
2. Select **New > Scripting Backend** from the pop-up menu. This will open the **New Scripting Backend Configuration** wizard.
3. Click **Show external** button which will open a selection window displaying information about all available scripting backends from repository. If no internet connectivity is available, the wizard will recommend to check internet connection before proceeding with the download. Note that in certain environments, the user can get access to internet only via HTTP proxy which requires a separate configuration detailed in How to Configure HTTP Proxy Settings for External Scripting Backends.
4. Select a specific scripting backend from the list and click **OK**.
5. Click **Finish** to exit the wizard and deploy the selected scripting backend. The selected scripting backend will be added to the test design configuration if it doesn't already contain selected scripting backend.

External scripting backends are downloaded to the Eclipse workspace containing the Conformiq project to which the scripting backend is added (the exact file location is *<Eclipse workspace>/.metadata/.plugins/com.conformiq.qtronic.client/<scripter.jar>*).

Checking and Installing Available Update

If the Conformiq Eclipse Client has an access to the internet, whenever user accesses the scripting backend wizard, the Conformiq Eclipse Client will automatically check for available updates on the scripter. Any updates are indicated to the user in scripting backend list. In

order to use updated version, user is required to update and add scripting backend with the design configuration. In addition, when user starts test case rendering, Conformiq Designer will perform a software update check for the selected scripting backend from the external repository. If a new version of the given backend is available, a notification to update scripting backend will be shown.

The scripting backends are updated and added to design configurations as follows:

1. Select a test design configuration from the Project Explorer to which the scripter is added.
2. Select **New > Scripting Backend** from the pop-up menu. This will open the **New Scripting Backend Configuration** wizard.
3. Select scripting backend which indicates *update available* status and click **Update downloads** button. An old version will be replaced with the update in Designer workspace.
4. Click **Finish** to exit the wizard and deploy the selected scripting backend. The selected scripting backend will be added to the test design configuration.
5. If the user decides to cancel the operation, click **Cancel** to exit from the wizard. Note that, in this way updated scripter will not be added to the design configuration.

How to Configure HTTP Proxy Settings for External Scripting Backends

In order to get access to the scripting backend warehouse in an environment that requires setting up HTTP proxy, the HTTP proxy settings must be defined in Eclipse as follows:

1. Select **Window > Preferences > General > Network Connections**.
2. Select **Manual** from **Action Provider**' drop down list.
3. Select **HTTP** in the list and click **Edit** button

4. Fill in the proxy server host name and port number. If needed, fill in the user name and password.
5. Click **OK**

3.12.2 How to Use Script Backends Shipped with Conformiq

This section describes how to configure script backends that are shipped with Conformiq. Each scripting backend has its own set of configuration options. The configuration dialog opens by double clicking the scripting backend in the Project Explorer.

Adding the variable ${QTRONIC.PROJECT} into a field is substituted with the name of the project in the actual string passed to the scripting backend, e.g., if in a project "Foo" there is a setting "Base directory" and the field reads "my${QTRONIC.PROJECT}Bar" the scripting backend would be passed the value "myFooBar" for the setting "Base directory".

How to Use HTML Scripting Backend

The HTML script back-end saves the test plan as an HTML file. A generated HTML file can be viewed with any modern web browser that supports JavaScript and Cascading Style Sheets. The HTML script backend is configured using the following configuration options:

Main / Generated HTML file

Selects the output file. The output file name should have the format <DIRECTORY>/<INDEX PAGE>.html, for example /tmp/testcases.html or C:\testcases.html. The default is "testcases.html".

Customizations / Multi page output

If enabled, each test case is generated to a separate file. In addition, an index page is generated that contains links to the test case files. By default this is enabled.

Customizations / Display probabilities

Displays the probabilities of test cases (see Section Probabilities and Priorities). By default this is disabled.

Customizations / Separate lifelines for ports

Shows separate lifelines also for ports on the tester side. By default this is disabled in which case only lifelines for the tester and for all the threads active in the given test case will be visible.

Customizations / Input port suffix

Omit port suffix from an input port. With this option it is possible to combine lifelines of unidirectional input and output ports to a single lifeline that represents a single bidirectional port. This option is only applicable when "Separate lifelines for ports" is enabled. The default value is "_in". For example, if the model contains input port "X_in", and output port "X_out", and both "Input port suffix" and "Output port suffix" have been left as default values, the plugin generates a separate lifeline named "X", which contains both inputs of "X_in" and outputs of "X_out".

Customizations / Output port suffix

Omit port suffix from an output port. With this option it is possible to combine lifelines of unidirectional input and output ports to a single lifeline that represents a single bidirectional port. This option is only applicable when "Separate lifelines for ports" is enabled. The default value is "_out".

How to Use TTCN-3 Scripting Backend

The TTCN-3 scripting backend generates TTCN-3 test cases, enabling deployment of model-based testing with a TTCN-3 test execution environment. The TTCN-3 scripting backend publishes tests generated by Conformiq Designer automatically in multiple TTCN-3 files which can be compiled "as is" with TTCN-3 tools. To execute tests against a real system under test harness, TTCN-3 functions which are called from test cases have to be provided or specified. In addition, a TTCN-3 runtime environment, codecs and test adapter

implementations are required to execute tests.

The TTCN-3 scripting backend has the following configuration options:

Main / Test suite file

Target file for generated test cases. The default value is "CQ_TestSuite.ttcn3".

Main / Import from or generate to data types file

Either target file for generating TTCN-3 protocol data types or file from which existing TTCN-3 protocol data types are to be imported from. In both cases, module name is assumed to be same as file name. The default value is "CQ_Types.ttcn3".

Main / Generate protocol data types

If checked, all TTCN-3 protocol data types will be generated from QML types to the specified data type file. By default is enabled.

Main / Import from or generate to test system file

Either target file for generating TTCN-3 component and port types or file from which existing TTCN-3 component and port types are to be imported. In both cases, module name is assumed to be same as file name. Default value is "CQ_TestSystem.ttcn3".

Main / Generate test system information (component and port types)

If checked, all TTCN-3 component and data types will be generated from QML types to the specified test system file. By default is enabled.

Main / Import from or generate to harness template file

Either target file for generating test harness TTCN-3 functions or file from which existing test harness TTCN-3 functions are to be imported. In both cases, module name is assumed to be same as file name. Default value is "CQ_TestHarnessTemplate.ttcn3".

Main / Generate test harness function stubs

If checked, documented TTCN-3 function stubs will be generated for required test harness functions. If target file exists it will not be rewritten. By default is enabled.

Main / Import from or generate to default altstep file

Either target file for generating default altstep or file from which existing default altstep are to be imported. In both cases, module name is assumed to be same as file name. Default value is "CQ_Defaults.ttcn3".

Main / Generate default altstep

If checked, default altstep will be generated for required test harness functions. If target file exists it will not be rewritten. By default is enabled.

Customization / Extra import statements

List of all additional TTCN-3 import statements that are needed to make the TTCN-3 test suite file compile. By default this field is empty.

Customization / MTC type name

The type name for the TTCN-3 main test component (MTC) on which all generated test cases run. Default value is "CQ_MTC".

Customization / System component type name

The name of the TTCN-3 component to be used in the system clause of all generated test cases. Default value is "CQ_TestHarnessSystem".

Customization / Start test case hook function name

The function name that is invoked in every generated test case just before the (optional) activation of default. If not empty, semicolon is added automatically so user can have e.g. `start_case()`. Default value is "start_test_case()".

Customization / End test case hook function name

The function name that will be invoked in every generated test case, just after the

deactivation of the optionally activated default, as well as in the case of an unexpected event occurring in the default. Default value is "end_test_case()".

Customization / Default altstep name

Name of the generated TTCN-3 default statement with parameters if needed but without semicolon. Default value is "a_cq_default()".

Customization / Default variable name

Name of the variable used to manage (optional) activation of the generated TTCN-3 default. Default value is "v_cq_default".

Customization / Component timer name

Name of the generated timer used to check that the SUT responds within some specified time limit. Default value is "t_cq_timer".

Customization / Generated functions prefix

Prefix to be used when generating TTCN-3 function names. Default value is "f_cq_".

Customization / Generate fractions for float numbers

By default, float values are generated as decimals and truncated after 20 digits. This option is used to generated fractions instead of decimals, e.g., `1/3` instead of `0.3333...` By default is disabled.

Customization / Generate textual MSC in test case documentation

If checked, a textual *message sequence chart* will be generated as part of every test case documentation. By default is disabled.

Customization / Show external ports in textual MSC

If checked, the textual message sequence chart will use external port instead of component names for labeling life lines. By default is disabled.

Customization / List targeted goals in test case documentation

If checked, a list of testing goals targeted by each test will be included in the test case documentation. Note that only testing goals which are enabled in the Logging configuration tab will be listed. By default is disabled.

Customization / Show all messages in TTCN-3 comments

If checked, internal messages are also reflected in TTCN-3 comments within each test case - otherwise only external messages are shown. By default is enabled.

Timing / Maximum SUT response time

Maximum valid response time for any message sent by the SUT. After this time limit expires, the test verdict will be set to fail and test will be terminated. Default value is 10.0.

Logging / Log function name

This option allows calling custom log functions. The default setting is the TTCN-3 log statement. Default value is "log".

Logging / Log CQ debug messages

If checked, Conformiq debug messages will be included in the test cases as log statements. By default is enabled.

Logging / Log CQ info messages

If checked, Conformiq information messages will be included in the test cases as log statements. By default is enabled.

Logging / Log targeted Requirements

If checked, will log the coverage of requirements marked in the QML model which are targeted in each test. Module parameters can be used to turn off this coverage information during execution. By default is enabled.

Logging / Log targeted Use cases

If checked, will log the coverage of use cases marked in the QML model which are targeted in each test. Module parameters can be used to turn off this coverage information during execution. By default is enabled.

Logging / Log targeted States and Transitions

If checked, will log the coverage of QML model states and transitions which are targeted in each test. Module parameters can be used to turn off this coverage information during execution. By default is disabled.

Logging / Log targeted Conditional and Atomic Branches

If checked, will log the coverage of conditions and branches in the QML model which are targeted in each test. Module parameters can be used to turn off this coverage information during execution. By default is disabled.

Logging / Log targeted Boundary Value Analysis

If checked, will log the coverage of QML model boundary value conditions which are targeted in each test. Module parameters can be used to turn off this coverage information during execution. By default is disabled.

Logging / Log targeted Methods

If checked, will log the coverage of methods defined in the QML model which are targeted in each test. Module parameters can be used to turn off this coverage information during execution. By default is disabled.

Extensions / Use port type extension

This option is TTCN-3 tool specific. Do not use unless your tool supports non-standard port extensions. By default this field is empty.

How to Use TCL Scripting Backend

The TCL script backend generates test scripts in TCL, enabling employment of model

driven testing in a TCL environment. With the TCL script back-end, TCL test cases can be derived automatically from a functional design model and be executed against a real system.

The TCL script backend is configured using the following configuration options:

Main / Generated TCL file

Selects the output file. The output file name should have the format <DIRECTORY>/<SCRIPT>.tcl, for example /tmp/TestSuite.tcl or C:\TestSuite.tcl. The default is "TestSuite.tcl".

Test case template / Template TCL file

The location of the test case template used. This file contains extra code that can be inserted before and after Conformiq generated test cases, such as initialization and de-initialization of a test harness. The default is "Teamplate.tcl"

Test case template / Generate stub template

Generate a stub test case template file if one does not exist. By default this has been enabled.

Test harness / Test harness TCL file

The location of the TCL test harness file, i.e., the library file which contains the implementation of the routines that the scripting backend generates. The default is "TestHarness.tcl".

Test harness / Test harness include method (source|embed)

Source / embed the generated test harness to the script. Bt default this is set to "source".

Test harness / Generate stub library

Generate a stub library file if one does not exist that contains the default implementation of the routines that the scripting backend generates. By default this has been enabled.

Customizations / Comment test case as an MSC

Depict the test case as a message sequence chart (MSC) in a comment block above the test case implementation. By default this has been enabled.

Customizations / Dump requirement traceability information

Dump requirement tracebility information to the script that shows which test cases cover which requirements. By default this has been enabled.

Customizations / Dump structural feature traceability information

Dump structural feature tracebility information to the script that shows which test cases cover which structural features of the model. By default this is disabled.

Customizations / Dump test dependency information

Dump test dependency information that shows how test cases depend on each other. This option is only applicable when 'OSI Methodology Support' has been enabled in Conformiq. By default this is enabled.

Customizations / Array member separator

The separator of QML level array members in TCL. By default this is ",".

Customizations / Add timestamps to test steps

Add timestamps of the message take overs to test steps. By default this is disabled.

Customizations / Omit port prefixes (port_in -> in)

Omit QML port prefixes, i.e., convert port names such as "some_port_in" to "in". By default this is disabled.

Customizations / RSD-RT Model

Enable conventions of RSD-RT to be used in the generated script. By default this is disabled.

Customizations / Dump Conformiq configuration

Dump the configuration of Conformiq at the beginning of the script file. This

configuration information includes, for example, the name of the Conformiq project from which the script has been generated, all the algorithmic options, and all the coverage settings. By default this is disabled.

Customizations / Highlight actions in code

Surround test steps in the script with comment blocks so that they become "highlighted" in the generated script. By default this is disabled.

Customizations / Add indexes to variable names

Append an index number to generated variable names. Enabling this option prevents variable name clashes. By default this is enabled.

How to Use Perl Scripting Backend

The Perl script backend generates test scripts in Perl, enabling employment of model driven testing in a Perl environment. With Perl script backend, Perl test cases can be derived automatically from a functional design model and be executed against a real system.

The Perl script backend is configured using the following configuration options:

Main / Generated Perl file

Selects the output file. The output file name should have the format <DIRECTORY>/<SCRIPT>.pl, for example, /tmp/TestSuite.pl or C:\TestSuite.pl. The default is "TestSuite.pl".

Test harness / Test harness Perl module

The location of the Perl test harness module, i.e., the Perl module which contains the implementation of the routines that the scripting backend generates. The default is "TestHarness.pm".

Test harness / Generate stub harness module

Generate a stub harness module if one does not exist that contains the default implementation of the routines that the scripting backend generates. By default

this is enabled.

Customizations / Comment test case as an MSC

Depict the test case as a message sequence chart (MSC) in a comment block above the test case implementation. By default this is enabled.

Customizations / Add timestamps to test steps

Add timestamps of the message take overs to test steps. By default this is disabled.

Customizations / Omit port prefixes (port_in -> in)

Omit QML port prefixes, i.e., convert port names such as "some_port_in" to "in". By default this is disabled.

Customizations / Dump Conformiq configuration

Dump the configuration of Conformiq at the beginning of the script file. This configuration information includes, for example, the name of the Conformiq project from which the script has been generated, all the algorithmic options, and all the coverage settings. By default this is disabled.

Customizations / Highlight actions in code

Surround test steps in the script with comment blocks so that they become "highlighted" in the generated script. By default this is disabled.

How to Use Excel Scripting Backend

The Excel scripting backend generates an Excel file with tests generated by Conformiq Designer rendered as tables with textual instructions, enabling the use of such tables for manual testing or as an alternative means of test documentation. With default settings the Excel scripting backend produces a mapping file and a test suite file. The test suite file contains all textually rendered tests in one worksheet and the traceability matrix with all covered goals in separate worksheet. The Excel group feature can be used to easily collapse and expand individual test descriptions in the test suite worksheet or coverage groups in the traceability worksheet.

The mapping file contains four worksheets which define default mappings of actions, identifiers and values to text - essentially a dictionary for transforming QML test steps to instructions. The generated mapping file can then be further customized manually. Changes to mappings will not be overwritten even when the "Generate or update mapping file" option is checked. The test suite file will be overwritten by the scripting backend.

The Excel scripting backend supports also narrative tags. The text produced from them is printed into test summary field of each test which is left to be filled in otherwise. Current limitations of the Excel scripting backend are that it can not handle the mapping of nested records and array values. It also does not process scenario tags.

The Excel scripting backend has the following configuration options:

General / Output file

Target name (and directory) for Excel file containing the generated test cases. The default value is "ExcelTestSuite.xls"

General / Mapping file

Either target or source name (and directory) for Excel file containing the mapping of actions, identifiers and values to text. The default value is ""ExcelMappings.xls".

General / Generate or update mapping file

If checked and mapping file does not exist, will generate complete mapping file. If checked and it exists will update mapping file by adding missing actions, identifiers and values but leaves changes to existing mappings as is. By default is checked.

General / Configuration message type

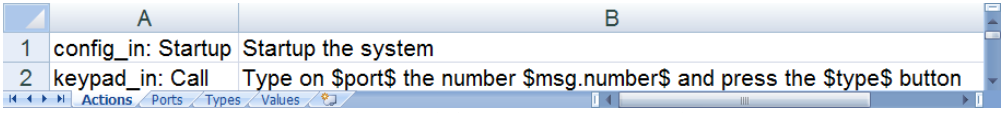
If specified, the value or content of messages of this type will be used to create pre-condition cells for tests. Messages of this type must always appear as first input in every test to be processed as preconditions by this backend. If they appear later they will be processed as an action. By default the field is empty.

General / Verdict values

Allows to specify a list of verdict values to be generated in a drop down menu of each verdict cell in the generated test suite worksheet. Values must be comma separated. The default value is "Verdict values" value="Open, Pass, Fail, Not_Executable".

To produce more application or domain specific prose in the test suite worksheet, the default mapping generated into Excel mapping file should be customized. This be achieved by changing the default mappings contained in 4 different worksheets "Actions", "Ports", "Types", and "Values" and by using "$port$", "$type$", and "$msg.<field name>$" tags in action strings. In the most important worksheet is the "Actions" worksheet where column A lists all action identifiers relevant in the test suite (syntax: "<QML port name>:<QML message type>"), and column B lists the corresponding action string to be used for them. The backend writes this string in a test step cell in the test suite worksheet whenever it encounters this port-stimulus/response pair in the tests produced by Conformiq Designer.

Actions Worksheet Mapping Examples



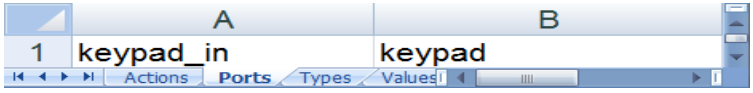
Actions Worksheet Mapping Examples

These mappings would produce out the strings "Startup the system" and "Type on keypad_in the number 123456 and press the Call button" in every case, e.g., a Startup message is to be sent to the config_in port. Note that in the case of the Startup message example the string is written out regardless of the field values that this message may contain.

"Ports", "Types" and (Boolean) "Values" worksheets can be used to transform also QML identifiers prior to their use in action strings. In these sheets A column contains the identifier to be transformed and the column B the string to be used. In case of value mappings column A contains the message field identifier, column B, D and E contain value identifiers, i.e., "true", "false" or "omitted" (in case of optional fields), and column C, F and G contain the

string values to be used instead of these values in the action strings.

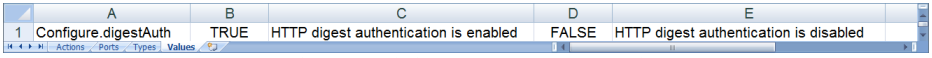
Ports Worksheet Mapping Example



Ports Worksheet Mapping Examples

Combined with the previous action string example this mapping would result now in the text "Type on keypad the number 123456 and press the Call button" in corresponding test steps of the test suite.

Values Worksheet Mapping Example



Values Worksheet Mapping Examples

This example shows how Boolean values can be mapped to more understandable text and would produce "HTTP digest authentication is enabled" in all "Configure" action strings where "$msg.digestAuth$" is used and its QML value is "true".

How to Use OpenDocument Scripting Backend

The OpenDocument script backend saves the test plan in ODT or OpenDocument format. ODT (http://en.wikipedia.org/wiki/OpenDocument) is XML based format for representing word processing documents and such and is directly supported in word processing tools such as OpenOffice and MS Word (support was released in Word 2007 SP2).

The ODT script backend is configured using the following configuration options:

Output / Generated file

> Selects the location of OpenDocument file to be generated, for example /tmp/testplan.odt or C:\testplan.odt. The default is "testplan.odt".

Templates / Use custom test suite template

Use custom ODT template file for test suite summary. By default this option is set to false.

Templates / Test suite template file

Location of the custom ODT template file for test suite summary. The value is only used if the 'Use custom test suite template' option has been enabled.

Templates / Use custom test case template

Use custom ODT template file for individual test cases. By default this option is set to false.

Templates / Test case template file

Location of the custom ODT template file for individual test cases. The value is only used if the 'Use custom test case template' option has been enabled.

How to Use JUnit Scripting Backend

The JUnit script backend saves the test plan in directly executable JUnit format. JUnit is a simple, open source framework to write and run repeatable tests in Java programming language. It is an instance of the xUnit architecture for unit testing frameworks.

The JUnit script backend is configured using the following configuration options:

Preferences / Output folder

The output folder, where the root package will be generated to. The default value is "junit".

Preferences / Root package

The root package name for generating JUnit project. The default value is "CQGenerated".

Preferences / Test case class prefix

Names of the classes representing test cases will start with this prefix. The default value is "TestCase".

Preferences / Record class prefix

Names of the classes representing QML records. This prefix is added to their names at the beginning. The default value is "CQRecord".

Preferences / Generic harness interface name

Interface name representing test harness. The default value is "HarnessCode".

Preferences / Generate function stubs for test harness implementation

If checked, a class with method stubs for implementing the test harness will be generated. If target file already exists, it will not be overwritten. If unchecked existing test harness implementation class will be imported.

Preferences / Name of class implementing the test harness

Qualified name of class implementing test harness interface. For example 'com.conformiq.HarnessImpl'. The setting is ignored in case if test harness implementation class is automatically generated. The default value is "DefaultHarnessCodeImpl"

Customizations / Generate textual MSC in test case description

If checked, a textual message sequence chart will be generated as part of every test case description.

Customizations / Add port names to test harness method names

If checked, the scripting backend will add port name to test harness method names for example sendMessageToPort and receiveMessageFromPort.

How to Use QTP Scripting Backend

The QTP script backend saves the test plan in QTP or QuickTest Professional format. HP QuickTest Professional is an automated testing software that performs functional and regression testing. It works by identifying the objects in the application user interface or a web page and performing desired operations. QTP uses *VBScript scripting language* to specify the test procedure and to manipulate the objects and controls of the application under test. The QTP scripter creates the actual executable script in VBScript format while it creates a full QTP project that can be then opened and executed in HP QuickTest Professional.

The QTP script backend is configured using the following configuration options:

Output / Path

> Selects the output directory. The output file name should have the format <DIRECTORY>/<SCRIPT>, for example /tmp/out or C:\out. The default value is "out".

Output / Generate stub harness module

> Generate a stub harness module if one does not exist that contains the default implementation of the routines that the scripter generates. The default value is true.

How to Use TestPlan Scripting Backend

The TestPlan script backend saves the test plan in HTML format in an alternative format from the HTML Scripting Backend. The documentation generated by the TestPlan scripting backend can be customized by editing "plan.js" file (that gets automatically generated the first time the scripter is executed).

The TestPlan script backend is configured using the following configuration options:

Main / Generated test plan

> Select the location of HTML test plan file to be generated, for example /tmp/testplan.html or C:\testplan.html. The default value is "testplan.html".

Framework / Generate file for detailing test steps

Generate a file for detailing the test steps if one does not exist that contains the default implementation of the routines that the scripter generates. If the file already exists, it will not be regenerated. The default value is true.

Framework / File for detailing test steps

Location of the file for detailing the test steps. The default value is "plan.js".

3.13 Test Case Management

The generated test cases in Conformiq can be managed and analyzed in the Conformiq Eclipse Client user interface. The different views that can be used in the analysis of test generation results were covered in Section How to Analyze Test Generation Results. *Test Case Management* is another very important feature in Conformiq: the results of test generation runs are stored on a persistent data storage that can be managed using the Conformiq Eclipse Client.

Persistent Storage for Test Cases

Conformiq stores the results of test generation on persistent data storage every time the test cases are updated. This means that the results from the past test generation runs are not lost if the model is updated and the test cases are regenerated. However, when the model is updated, the updates may render some of the existing test cases invalid as they do not reflect the external behavior of the model any longer. Also, test cases may become invalid if they cover features in the model that were previously targets (or "do not cares") but are now blocked. (See Section How to Configure Design Configuration Specific Testing Parameters for more information about coverage options and settings.) It is also possible that after a change has been made to the model, some of the test cases remain valid, but Conformiq Designer can find a test suite that is more optimal that actually does not include a test generated earlier. These tests are marked as *redundant* test cases, as the selected test suite contain test cases that cover the same aspects that a redundant test covers, but with *smaller*

price.

The previously generated test results are also used as an incremental input for future test generations: When generating test cases, Conformiq Designer first analyzes existing test cases to see which of them are still valid with respect to the external behavior of the model. Once the incremental analysis is over, Conformiq Designer runs an incremental algorithm to augment the existing test set with additional test cases if this is required. When tests are regenerated due to a change in the model etc., there is no need to regenerate tests from the parts of the model that are not changed. Thus, if the existing test set covers all the target coverage goals (See Section How to Configure Design Configuration Specific Testing Parameters for more information about coverage goals), there is no need to generate more test cases, and Conformiq Designer will stop before running the incremental test generation algorithm.

When analyzing the test generation results, the following rules apply to the representation of the generated test cases, whether valid, redundant, or invalid:

- When you click a Conformiq project in the Project Explorer of the Conformiq Eclipse Client user interface, the Test Case List view will show *all* the generated test cases for that project: you see the test cases from all the test design configurations that are part of the particular Conformiq project. This set of test cases also includes those test cases that are no longer valid, i.e., test cases that do not represent the updated external behavior that the model exhibits, but also the redundant test cases. The invalid test cases are presented in red to differentiate them from the valid test cases that properly represents the behaviors while redundant test case are presented in orange.
- When you click a test design configuration in the Project Explorer of Conformiq Eclipse Client, the Test Case List view will show *only* those test cases that were generated using the test design configuration specific coverage settings. In addition, this view always shows only valid test cases, never invalid or redundant ones.

A test case can "belong" to multiple test design configurations at the same time because it can be valid over multiple test design configurations, i.e., a test case can be shared by more than one test design configuration.

Note that because scripter plugins are always part of test design configurations, when test cases are rendered, only those test cases that belong to the given test design configuration are rendered using the particular scripter plugin. There is no way to render invalid and redundant test cases.

If the update to the model that caused the invalidation of some test case is reverted, the invalidated test case becomes valid once again, so it is "moved" back to the test design configuration where it was valid in the beginning. In addition, this test case is once again marked as valid in the project wide test case list (i.e., it is no longer rendered in red).

Naming Test Cases

As mentioned in the Section Test Case List, the generated test cases have names so they can be identified and differentiated from one another. As the test cases are persistent, the names of the test cases are persistent also, and they remain the same even if the test cases are regenerated.

See Sections Intelligent Test Case Naming and Test Case List for more information about automatic test case naming, how to rename the test cases, etc.

Deleting Test Cases

The generated test cases are stored in persistent data storage and they remain "live" across model reloads and test generations.

To delete all of the test cases owned by the Conformiq project, follow these steps:

1. Select the Conformiq project in the Project Explorer view.

2. Select **Conformiq > Delete Test Cases** from the pop-up menu. This will delete all the test cases owned by the project.

Note that when test cases are deleted from the project, there are no incremental test assets for future test generation runs. Instead, Conformiq Designer needs to start the test generation all over again.

WARNING There is no way to undo test case deletion from a project: deleted test cases are immediately deleted from the persistent data storage.

3.14 Managing Conformiq Projects

The central hub for data files in Eclipse is called a *workspace*. A workspace houses a collection of projects that were already discussed in the Section How to Work with Conformiq Projects. Each project is stored in the file system under the workspace location. Each project folder stored in the file system contains information related to the given Conformiq project, namely model files, coverage settings, generated results, and so on.

It is recommended to generate a distinct workspace for Conformiq related projects. This makes it easier to work with different Eclipse based applications: whenever you start a new Eclipse based application, you give it its own workspace. Switching between different projects is flexible this way, because instead of opening and closing different projects and trying to find the right project to work with, you just switch the entire workspace. The current workspace for Eclipse can be switched by selecting **File > Switch Workspace** from the Eclipse menu bar.

As the workspace is the central hub for the user data files and project folders it contains all the information for each Conformiq project, it is the Conformiq project folder that is stored into a version control system or sent around to another computer. The structure below

represents an example Eclipse workspace containing a Conformiq project named *SIPClient*:

```
workspace
   Conformiq
     SIPClient
       .database
       .metadata
       .project
       .qtronic
       .settings
         org.eclipse.core.resources.prefs
       model
         SIPClient.cqa
         SIPClient.xmi
```

As mentioned in Section How to Select Models, model files can be either imported (copied) into the project folder, or we can establish file links to model files. In the former case, the actual model files are stored to the version control also, while in the latter one, only the file link to the actual model file is stored, not the model file itself.

In addition to being the storage location, for example, for model files and several configuration settings, the Conformiq project also contains all the information about the test generation results. Therefore, sharing the Conformiq project with other users (via version control, for example) enables them to get access to the test generation results as well.

3.15 Command Line User Interface

Conformiq Designer includes support for running test generation from the command line instead of opening the Eclipse user interface, allowing the user to run the tool without a graphical user interface. The console based user interface directly utilizes the resources in an existing Conformiq project in an Eclipse workspace. This user interface provides both interactive and batch modes.

The console based user interface is started by providing an Eclipse workspace and an existing Conformiq project within the workspace as command line arguments.

Interactive Mode

The interactive console application is started by running *designerbatch* as follows

```
designerbatch <worspace location> <Conformiq project>
```

So for example

```
designerbatch /home/user/workspace SIP\ UAC
```

Once started, the console application reads all the configuration options, license details, existing test assets, etc. from the Conformiq project. It will then contact the Conformiq Computation Server configured in your Eclipse workspace preferences (**Window > Preferences > Conformiq**). The console based client will automatically start the Conformiq Computation Server if you have not configured Conformiq Eclipse Client to use a remote Conformiq Computation Server. At the end of the initialization, the licensing information is validated.

After the initialization, the console application enters a dispatch loop where you can:

Load model

Model is loaded to the Conformiq Computation Server by pressing **1** on the keyboard in which case the model files in the Conformiq project are loaded to the Conformiq Computation Server which then imports the model. The status information, in addition to warning and error messages, is shown in the console output.

Generate tests

The actual test generation is started by pressing **2** on the keyboard. As the test generation progresses, the console output will show the status of the test generation.

Render tests

The Conformiq generated test cases can be exported by pressing **3** on the keyboard. The operation will export test cases through all the enabled scripting backends present in the Test Design Configurations in the given project. The console output will show the status of the test rendering.

Delete test cases

The test database can be cleared by pressing **4** on the keyboard.

Exit

The console application can be terminated by pressing **5** on the keyboard. Each operation can be canceled by pressing "X" in which case the console application gives the same options as you have in the graphical Eclipse user interface. If the test generation is canceled, the console application will present you two possibilities: *Merge* and *Discard* (see Section How to Generate Tests for more information about the before mentioned alternatives)

Batch Mode

The batch mode is started by running *designerbatch* as follows

```
designerbatch <worspace location> <Conformiq project> <batch mode options>
```

So for example

```
designerbatch /home/user/workspace SIP\ UAC -l -g
```

The command line options for batch mode are

Option	*Description*
-l	Load the model files in the Conformiq project to the Conformiq Computation Server which then imports the model. The status

	information, in addition to warning and error messages, is shown in the console output. The program exits after the model has been loaded.
-g	Generate tests from the model. As the test generation progresses, the console output will show the status of the test generation. The console application will automatically also load the model to the server when given **-g** command line option. The program exits after the test generation ends.
-r	Export Conformiq generated test cases through all the enabled scripting backends present in the Test Design Configurations in the given project. The console output will show the status of the test rendering. If given **-g** in addition, the console application will first generate the test cases and then export them via scripting backends. Otherwise the tests that are present in the Conformiq project database will be exported without first running the test generation. The program exits after the test cases have been exported.
-x	Delete tests from the test database. If given in addition with **-g**, the application will clear the test database before running test generation. It's not allowed to combine **-x** option with other batch mode options expect **-g**.

Just like in interactive mode, the console application, prior to running the actual operation, reads all the configuration options, license details, existing test assets, etc. from the Conformiq project. It will then contact the Conformiq Computation Server configured in your Eclipse workspace preferences (**Window > Preferences > Conformiq**). The console based client will automatically start the Conformiq Computation Server if you have not configured Conformiq Eclipse Client to use a remote Conformiq Computation Server. At the end of the initialization, the licensing information is validated.

So for example

Load the model and generate tests

```
designerbatch /home/user/workspace SIP\ UAC -g
```

Render existing tests from the test database

```
designerbatch /home/user/workspace SIP\ UAC -r
```

Clear the test database and exit

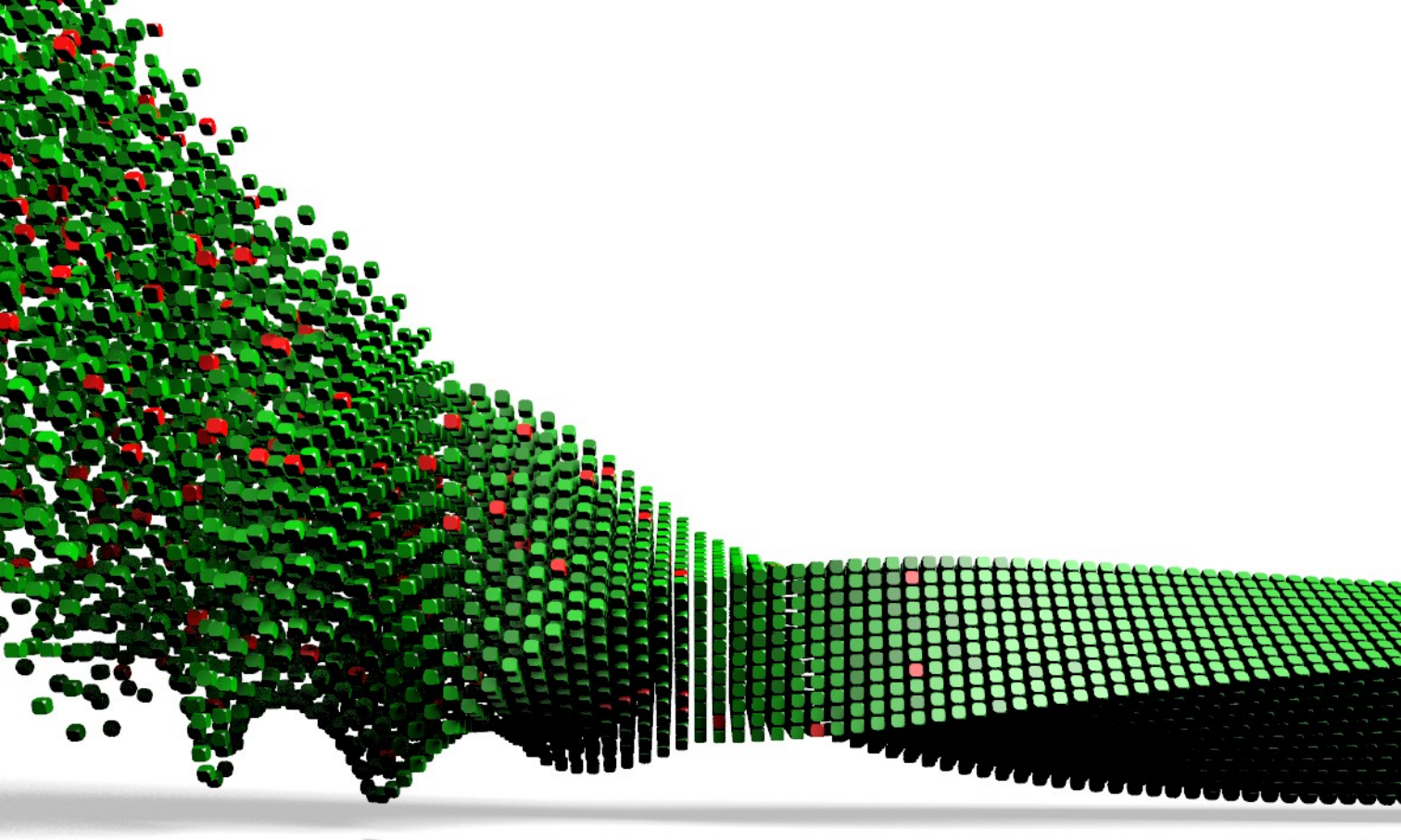
```
designerbatch /home/user/workspace SIP\ UAC -x
```

Load the model and generate tests, but before, clear the test database from existing test cases

```
designerbatch /home/user/workspace SIP\ UAC -x -g
```

Load the model, generate tests, and finally export the test generation results thru scripting backends. As above. start by clearing the test database from existing test cases before

```
designerbatch /home/user/workspace SIP\ UAC -x -g
```



4 Creating Models in QML

One of the formalisms that can be used to express design models is the **Conformiq Modelling Language** (QML). In QML, design models can be expressed entirely using textual notation, which is essentially a superset of Java with some ideas from C#, or with graphical notation, where models are described using UML state machines with the QML textual notation as an action language.

4.1 Textual Notation of QML

QML is an object-oriented language that can be used to describe design models. The textual notation is essentially a superset of Java with some variations. In this document we describe only those features of the QML textual notation that are different from "standard Java".

At a glance, compared to standard Java, the QML language is restricted or enhanced in a few ways, including but not limited to the following:

- There can be global variables and global methods. Globals have public visibility.
- The main entry point is not a static member method like in Java, but rather a global function that takes no parameters and returns nothing. The name of the main entry point is `main` just like in C and C++.
- Generics in QML are not implemented as in Java 5.0 by using type erasure, but rather as templates like in C++. In this regard, Java generics are very different from QML templates: QML produces different types for each distinct template instantiation, which means that primitive types and methods can be used as template arguments also. Because of type erasure in Java, Java does not support arrays of parameterized types, while QML does.
- The syntax for invoking template methods is different from Java. In QML, type parameters are placed after the method name like in C++, rather than before.
- There is no boxing/unboxing of types, because it is not required. QML has nullable types (like in C#) which address the scenario where you want to be able to have a primitive type with a `null` value.

- In addition to reference types (classes and arrays), QML also has support for structured value types *record*s and *union*s.
- The inner classes in QML are semantically closer to the nested classes of C++ rather than the inner classes of Java. The inner classes in QML are roughly equivalent to the static inner classes of Java.
- There are no anonymous inner classes, records or unions in QML.
- Communication with the environment is carried out by using *ports* that are declared inside a *system* block.
- QML supports operator overloading.
- QML supports type aliases through the `typedef` keyword like in C and C++.
- QML supports implicit types for local variables: once an implicit type has been inferred during compilation it does not change.
- Currently there is no support for packages.
- Currently there are no enumerators.
- Annotations are not supported.
- The `goto` statement and labeled `break` and `continue` statements are not supported in QML.
- All user defined types have global visibility.
- The standard library of QML is very limited compared to the standard library of Java.

The convention is to name the QML textual notation files with the *.cqa* suffix.

4.2 Basic Language Features

The following topics introduce and discuss the essential components of the QML textual notation, a language for defining design models.

4.2.1 Keywords

The keywords of the QML textual notation are listed in the table below.

Keyword	*Meaning*
`abstract`	An abstract class or method.
`after`	An after event (from UML).
`and`	A logical AND (an alias to &&).
`assert`	An assertion that a condition holds.
`belongs_to`	Tests if the value of a variable is in the set of given values; for example `require msg.value belongs_to { 2, 3, 5, 7, 11, 13 };`. This construct can be used to eliminate some state space branching inside `require` statements that Conformiq Designer needs to perform when analyzing the model.
`boolean`	A boolean type.
`break`	Break out from a loop or `switch case` statement.
`byte`	An 8-bit integer type.
`case`	A case of a `switch case`.
`catch`	A clause of a `try` block catching an exception.
`char`	A character type.
`class`	A class type definition (classes are reference types).
`combine_all`	The "all" combinatorial mode. See Section Modeling Combinatorial Test Data for details.
`combine_allpairs`	The "allpairs" combinatorial mode. See Section Modeling Combinatorial Test Data for details.
`complete`	Indicates the end of an incomplete region in the model. See Section End Conditions for Test Generation for details.
`const`	A constant.
`continue`	Continues to the end of a loop.
`default`	The default clause of a `switch case`.
`do`	The top of a `do–while` loop.
`double`	An arbitrary precision floating point number (an alias to `float`).

`else`	The else clause of an `if` statement.
`enum`	An enumerated type (*currently not supported*).
`extends`	A super class definition (parent) of a class or a super record of a record.
`false`	One of the two alternative values of the `boolean` type.
`final`	A constant or a class, a record, or a method that cannot be reimplemented.
`finally`	A clause of a `try` statement that is always executed after exiting the `try` block.
`float`	An arbitrary precision floating point number.
`for`	A `for` loop.
`goto`	*QML does not support gotos*.
`if`	A conditional statement.
`implements`	Defines the list of interfaces that the class or record implements.
`import`	Import a library. All the libraries in QML are in the *conformiq* namespace.
`Inbound`	Defines an external inbound port in the system block.
`incomplete`	Indicates the beginning of an incomplete region in the model. See Section End Conditions for Test Generation for details.
`instanceof`	Tests if a variable is an instance of a type (this is not restricted to reference types as in Java).
`int`	An arbitrary precision integer.
`interface`	An abstract type with methods that the class or record must implement.
`long`	An arbitrary precision integer (an alias to `int`).
`narrative`	Insert a narrative tag to the model used in automatic test case naming and construction of test case description.
`native`	*Not supported*.
`new`	Allocates a new object or an array. Note that records are *not* created with `new`.
`nocoverage`	Marks a region with no coverage goals attached. See Section Regions

	with No Coverage Goals for more details.
`null`	The nil reference.
`Outbound`	Defines an external outbound port in the system block.
`omit`	The `omit` keyword specifies that the record field is omitted from the record instance. Provided for backward compatibility with Conformiq Test Generator adapters.
`operator`	Overloads an operator.
`or`	A logical OR (an alias to `||`).
`package`	*Not supported*.
`prefer`	The preferred value of a record field. See Section Preferred Values of Record Fields for more information.
`priority`	Adds a priority to the model. See Section Probabilities and Priorities for details.
`private`	A private modifier — a feature that is accessible only by the methods of *this* class or record.
`probability`	Adds a probability to the model. See Section Probabilities and Priorities for details.
`protected`	A protected modifier — a feature that is accessible by the methods of *this* class or record and in all the subtypes.
`public`	A public modifier — a feature that is accessible by all.
`record`	Defines a record type (a value type). Records are **the only** types that can be used to communicate with an environment.
`require`	Require that the boolean argument supplied is true.
`requirement`	Inserts a new requirement into the model.
`return`	Returns from a method or a function.
`scenario`	Insert a scenario tag to the model used in automatic test case naming and construction of test case description.
`short`	A 16-bit integer.
`static`	A feature that is unique to its class or record, not to an instance of the class or record.
`strictfp`	*Not supported*.

`super`	The direct super class of an instance of a class or record, or a constructor.
`switch`	A selection statement.
`synchronized`	*Not supported*.
`system`	Defines the system block which contains the declarations of the external ports used to communicate with an environment.
`this`	The implicit argument of a method, or a constructor of the *this* class.
`throw`	Throws an exception.
`throws`	*Currently not supported*.
`transient`	*Not supported*.
`true`	One of the two alternative values of the `boolean` type.
`try`	A block of code that traps exceptions.
`typedef`	Create a type alias (`typedef` of QML is similar to `typedef` of C and C++).
`union`	Defines a union type (a value type).
`var`	An automatic variable type — the type of a variable is inferred by the QML compiler.
`void`	Denotes a method that returns nothing.
`volatile`	*Not supported*.
`while`	The `while` loop.

4.2.2 Comments

Comments in the QML textual notation are just like in Java except that block comments are recursive. For example:

```
// This is a one line comment.

/* This is a block comment. */

/* This is a /* recursive */ block comment. */
```

Character encoding of comments in QML is UTF-8

4.2.3 Literals

A literal is the source code representation of a value of a primitive type, the String type, or the null type. Literals in the QML textual notation are as in Java.

- Integer literals are either decimal (base 10), hexadecimal (base 16), or octal (base 8).
- Floating point literals have a whole-number part, a point (represented by an ASCII period character), a fractional part, an exponent, and a type suffix.
- Boolean literals true and false.
- A character literal is expressed as a character or an escape sequence (7-bit ASCII), enclosed in ASCII single quotes. Lines are terminated by the ASCII characters LF or CR LF.
- A string literal consists of zero or more characters (7-bit ASCII) enclosed in double quotes.
- The nil reference, represented as the literal `null`.

4.2.4 Operators

Syntax	*Meaning*
	Arithmetic binary operators
+	Addition.
-	Subtraction.

`*`	Multiplication.
`/`	Division.
`%`	Modulus (returns the integer remainder).
	Arithmetic unary operators
`-`	Unary negation.
`++`	Increment (prefix and postfix).
`--`	Decrement (prefix and postfix).
	Comparisons
`==`	Equals.
`!=`	Not equal.
`>`	Greater than (applicable to numeric types only).
`>=`	Greater than or equal to (applicable to numeric types only).
`<`	Less than (applicable to numeric types only).
`<=`	Less than or equal to (applicable to numeric types only).
	Assignment operators
`=`	Assign.
`+=`	Add and assign.
`-=`	Subtract and assign.
`*=`	Multiply and assign.
`/=`	Divide and assign.
`%=`	Modulus and assign.
	Boolean operators
`&& and`	Logical AND.
`|| or`	Logical OR.
`! not`	Logical NOT (negation).
	Conditional expressions
`?:`	Conditional expressions use the compound operator `condition ? true-clause : false-clause`.
	String operators
`+`	Concatenation.
`+=`	Concatenation and assignment.

Note that bitwise operators (`~ & | ^ &= |= ^= << >> >>> <<= >>= >>>=`) are **not supported**.

As in Java, Boolean operators are short-circuited meaning that operators are evaluated from left to right until the result is determined. Operator precedences are given in the table below.

Operator	*Associativity*
`?:`	Right
`= += -= *= /= %=`	Left
`[] . ()` (method call)	Left
`!` `++` `--` `+` (unary) `-` (unary) `()` (cast) `new`	Right
`* / %`	Left
`+ -`	Left
`< > <= >= instanceof`	Left
`== !=`	Left
`&&`	Left
`||`	Left

4.2.5 Data Types

Just like Java, QML is a strongly typed language meaning that type of each variable and each expression is known at compile time.

Types in QML are divided into three groups: primitive types, reference types, and value types.

Opposed to standard Java, the type comparison operator `instanceof` is not restricted to comparing only reference types — `instanceof` in QML can be used to compare types of any kind.

Primitive Types

The primitive types of QML are the Boolean type (`boolean`), the integral types `byte`, `short`, `int`, and `long`, the floating point types `float` and `double`, and the character type

`char`.

Type	*Inclusive range*
	Integer types
`byte`	-128 to 127
`short`	-32768 to 32767
`int`	Arbitrary precision
`long`	Arbitrary precision
Floating point types	
`float`	Arbitrary precision
`double`	Arbitrary precision
	Boolean types
`boolean`	Boolean `true` and `false`
	Character types
`char`	0 to 65535

Note that `int` and `long` may hold arbitrary precision integer values. Therefore, there is no need for `BigInteger` of Java (actually `BigInteger` of QML is an alias to `long` which on the other hand is an alias to `int`). Similarly, `float` and `double` may hold arbitrary precision floating point values. Therefore, there is no need for `BigDecimal` of Java (actually `BigDecimal` of Conformiq Java is an alias to `double` which on the other hand is an alias to `float`).

Array Types and Strings

Just like Java, QML has an array for each type. Arrays are homogeneous types, meaning that each array member must have the same type (or they have to be sub-types of the array member types). Arrays have a read-only `length` attribute that contains the number of elements in the array. There are two ways to allocate arrays at run-time:

- Using the operator `new` which may also take expressions whose values are not known at compile time.
- Using array initializers which are shorthands for allocating an array object and

supplying initial values at the same time (new is not used with array initializers).

```
// Create an int array with 10 items using new.
int[] array1 = new int[10];
```

```
// Create an int array and supply the initial values.
int[] array2 = {1, 2, 3, 4, 5};
```

Arrays may be multi-dimensional — multi-dimensional arrays are actually just arrays of arrays.

```
// Create a two-dimensional array of Foos.
Foo[][] foos = new Foo[10][10];
for (int i = 0; i < foos.length; i++)
    for (int j = 0; j < foos[i].length; j++)
        foos[i][j] = new Foo();
```

Multi-dimensional arrays may also be constructed using array initializers.

```
int[][] array3 = { {1, 2}, {3, 4}, {5}, {6, 7, 8} };
```

Just like in Java, arrays are always reference types in QML.

In Conformiq Qtronic versions 1.0.X when an array containing objects was allocated using the operator new, each array member was also allocated using the default constructor, i.e., a constructor that does not take arguments. For this reason, QML always provided this constructor that takes no arguments if there was no such a constructor. Since Conformiq Qtronic 1.1.0 this has been changed so that array allocation is done just like in Java; when we allocate an array containing objects using the operator new, each array member is assigned a *null* value.

Note that the default value for an unallocated array is always *null*.

```
int[] array; // array == null
```

The `String` class represents constant character strings. All string literals, such as "foobar", are implemented as instances of the `String` class. Just like in standard Java, the QML language provides special support for the string concatenation operator `+`.

```
class String {
    /** Returns a new string that is a substring of this string. */
    public String substring(int begin);
    /** Returns a new string that is a substring of this string. */
    public String substring(int begin, int end);
    /** Instance variable that contains the length of the string. */
    public int length;
}
```

In Conformiq Qtronic versions 1.0.X an instance of `String` in the QML textual notation was actually just an array of `char`s. However, since Conformiq Qtronic 1.1.0 `String`s are objects just like in Java. Note that you can still use brackets to reference an item of a `String`.

Reference Types

As in Java, classes are reference types in QML. Class types are always created with `new`.

Classes may contain fields, methods, operators, type aliases, and nested (inner) types.

Classes may be

- *Abstract* (defined with the `abstract` modifier) — they cannot be instantiated. Abstract classes may (in addition to concrete classes) contain abstract methods which must be overridden in concrete subclasses that extend the abstract class. Abstract classes may not be final.

- *Final* (defined with the `final` modifier) — they cannot be sub-classed. Obviously, final classes may not be abstract.

Classes are always public regardless of whether they are on the top-level or nested.

QML supports single inheritance with a monolithic class hierarchy, just like Java does, and the super type of all the classes is `Object` just as in Java. Inheritance is further discussed in the Section Inheritance. `Object` in QML is defined as follows:

```
class Object {
    /** Creates and returns a copy of this object. */
    public Object clone();
    /** Returns a String representation of the object. */
    public String toString();
}
```

The syntax for declaring classes is as follows:

```
[modifiers] class identifier [type-parameters]
            [extends type] [implements type-list]
{
    [members]
}
```

`this` and `super` may be used inside classes just like in Java.

As mentioned above, a class may hold inner classes — classes that are defined inside another classes. The syntax for instantiating inner classes (or inner records or unions, for that matter) in QML is not the same as in Java. While in Java inner classes are instantiated as follows

```
Outer outer = new Outer();
Outer.Inner inner = outer.new Inner();
```

in QML inner classes are instantiated as follows

```
Outer.Inner inner = new Outer.Inner();
```

QML does not require an instance of the outer class to exist in order to create an instance of the inner class. Thus inner classes in QML are similar to the nested classes in C++ rather than the inner classes of Java, and they are roughly equivalent to the static inner classes of Java. In QML, inner classes can directly use type names and the names of static members from the enclosing class: unlike in Java, an instance of an inner class does not get access to both its own data fields and those of an outer object because there is no outer object.

Recall that arrays of reference types (see Array Types and Strings) are reference types themselves.

As in standard Java, at run-time, the result of the operator `==` (`!=`) is Boolean `true` (`false`) if the operand values are both `null` or both refer to the same object or array; otherwise, the result is Boolean `false` (`true`). For example

```
class C { public int value; }

void main()
{
    C c1 = new C();
    C c2 = new C();
    c1.value = c2.value = 1;
    assert c1 != c2;
    c1 = c2;
    assert c1 == c2;
    c1 = null;
    assert c1 == null;
}
```

Record Types

A record is a user-defined type similar to a class in the sense that they may contain fields, methods, operators, and nested types. They may inherit other records but they may not inherit classes or implement interfaces. However, a record type may be parameterized with

type arguments, just like classes.

The differences between classes and records are as follows:

- While classes are reference types, records are value types. Records are never created with `new`.
- Records may not mutate themselves through `this`. This means that records may not have constructors or member methods that mutate the members of `this`.
- Records may not have member variables that are nullables (see Section Nullable Types) or class types: records may hold fields of all the primitive types, the `String` type, other record types, and arrays.
- Records may contain nested types, but they must all be records. Type aliases may also be declared inside a record.
- Records are the only data types that may be used to communicate with an environment using `receive()`, `send()`, and `sync()` of `CQPort` (see Section Input and Output).
- Records may not implement interfaces.

Just like `Object` is the super type of all the class types, `AnyRecord` is the super type of all the record types. `AnyRecord` is a record that has no fields or members:

```
record AnyRecord { }
```

`this` and `super` may be used inside records just like inside classes.

The syntax for declaring records is almost identical to that of a class:

```
[modifiers] record identifier [type-parameters] [extends type]
{
    [members]
}
```

Example

```
record MyRecord {
    record MyInnerRecord {
        public int i = 1;
    }
    MyInnerRecord inner;
    public MyInnerRecord CopyInner()
    {
        MyInnerRecord r;
        r.i = inner.i;
        // Illegal:
        // inner.i = 10;
        return r;
    }
}

...

MyRecord r;
r.inner.i = 10;
MyRecord.MyInnerRecord inner = r.CopyInner();
```

Recall that arrays of records (see Array Types and Strings) are reference types. Also recall that the default value of an unallocated array is always *null*, therefore an unallocated array inside a record gets *null* as its default value. This means that whenever we reference an array field of a dynamic record value (a value that we have received from the environment, see Input and Output) we must first verify whether the field has a null value, otherwise we make a null pointer reference:

```
record X { int[] field; }
...
AnyRecord a = port.receive();
require a instanceof X;
X x = (X) a;
// Require that the integer array is not null
require x.field != null;
// Now that we know that integer array is not null so we can safely
// reference it.
require x.field.length == 2;
```

At run-time, the result of the operator `==` (`!=`) is Boolean `true` (`false`) if the operand values are of the same type and have recursively equal contents. For example

```
record R { public int value; }

void main()
{
    R r1, r2;
    r1.value = r2.value = 1;
    assert r1 == r2;
}
```

Optional Fields in Records

In QML, the elements of a record may be optional, therefore omitted. Optional fields are specified using the predefined special `Optional<T>` type.

For example.

```
record X {
    Optional<int> optint;
    Optional<X> optx;
}
```

If a record field is optional, the variables of that type can, but need not, have that field in

them. You can assign a new value with such a field to a variable with no such field and vice versa.

The `omit` keyword is used to specify that the field is omitted from the record instance. Optional fields are omitted by default.

The predefined function `ispresent<T>(T)` can be used to check if an optional field is present in a record variable. Note that it is a run-time error to reference an omitted record field. The signature of this function is given below.

```
boolean ispresent<T>(T field);
```

For example

```
void main()
{
    X x;
    // Optional fields are omitted by default, therefore it is a
    // run-time error to reference optional fields here.
    assert !ispresent(x.optint);
    x.optint = 1;
    assert ispresent(x.optint);
    assert x.optint == 1;
    x.optint = omit;
    assert !ispresent(x.optint);
}
```

Preferred Values of Record Fields

As mentioned earlier in this manual, at the heart of Conformiq Designer is a model inversion algorithm which "turns the model around" and derives tests for a system from a model that describes the same system. This algorithm needs to intelligently design the input data that will drive the system through the different scenarios that are required for testing.

Because this input data is computer-generated and not directly programmed into the model or from a hand written test data table, Conformiq Designer can, for example, select a value

"0" for an integer parameter of an inbound message if the model does not explain how the value of the given integer parameter would affect the behavior of the system. This "default behavior" of Conformiq Designer can be changed by explicitly modeling the fact that the *preferred* value of an inbound parameter should be something else, (something other than "0" in the case of this example) even if the model does not explain in more detail why a specific value should be selected when it does not affect the behavior of the system. These preferred values are specified using the `prefer` keyword in record definitions and they act as "hints" for the engine which then attempts to select the given preferred value for inbound data unless the behavior of the model forces the data to have some other value.

For example

```
record MyRecord
{
    int parameter prefer 10;
}

...

MyRecord r = (MyRecord) input.receive();
// The preferred value of r.parameter is 10 unless stated otherwise
```

The argument passed to `prefer` must be a constant value, i.e., a constant literal, a global Boolean constant variable, or an array initializer containing constants. The `prefer` keyword can be used exclusively in variable declarations inside record definitions the syntax being as follows:

```
type identifier [= initial-value] [prefer [constant-expression]]
```

The argument to `prefer` is optional and if omitted, the initial value of the variable will be used instead. Note that it is an error to omit the argument to `prefer` in a variable declaration that has no initial value defined. The following examples are all valid:

```
record Example
{
    int a;
    int b = 1;
    int c prefer 1;
    int d = 1 prefer 1;
    int e = 1 prefer;
}
```

Setting preferred values in record definitions is especially convenient in situations where an inbound data type contains numerous fields and the system is expected to check the validity of each input parameter but the order in which the SUT performs this check is undefined. If the model describes that the sequence of checks varies from the one that has been implemented in the real SUT, the execution of Conformiq Designer generated test cases may fail for the wrong reason; the field that the system checked first was different from what was modeled and caused the real system to behave differently than what the model explained. The following example illustrates this:

```
record MyInput
{
    int a;
    int b;
    int c;
}
record RejectDueA { }
record RejectDueB { }
record RejectDueC { }

...

MyInput x = (MyInput) input.receive();
if (x.a != 10)
{
    RejectDueA reject;
    output.send(reject);
}
else if (x.b != 15)
{
    RejectDueB reject;
    output.send(reject);
}
else if (x.c != 20)
{
    RejectDueC reject;
    output.send(reject);
}
else
{
    // OK
}
```

Now, if the real system carries out the check in a different order, e.g., first checks the validity of field *c*, then *b* and only then *a*, Conformiq Designer can design and generate a test case where the hypothetical tester sends a message with *a*, *b*, and *c* all set to "0" and then expects that the system responds with *RejectDueA*. However, the system first checks for *c* and as *c* differs from "20", it sends out a message *RejectDueC*. This causes the test to fail even though the system behaved correctly!

What we would like is for Conformiq Designer to generate tests where only the given field

contains an invalid value, so that the order in which the real system checks the message parameters becomes irrelevant. This can be modeled by using preferred values as follows:

```
record MyInput
{
    int a prefer 10;
    int b prefer 15;
    int c prefer 20;
}
```

When Conformiq Designer generates a test where field *a* differs from the valid value of "10", it will use the preferred values "15" for *b* and "20" for *c*. Now the order in which the real system checks the parameters is irrelevant and it is expected that the system will reject the Conformiq Designer generated input message due to an invalid value in field *a*, thus sending out the exact message expected.

Conformiq Designer does not apply preferred values to data fields in existing test assets (i.e., test cases generated previously), but preserves the existing values. For example, if we had in the above example an existing test asset that contains the value "11" for field *a* instead of the preferred value of "10", Conformiq Designer would not change the value of the field in the existing test asset from "11" to "10" even though the value "10" is preferred.

Note that Conformiq Designer fails to apply preferred field values for records that are contained in arrays ie in the following example, the preferred value for field *failure* is not applied.

```
system
{
    Inbound in: Y;
    ...
}
record X
{
    int failure prefer 345;
}
record Y
{
    X[] array;
}
```

Union type

A union is a user-defined value type similar to TTCN-3 and C++ unions. Similar to records, unions contain value-type fields and nested type definitions. A union in QML must contain at least one field. At most one field of a value of a union type may be *chosen* (active) at a time. Assigning to a field of a variable of union type erases the content of the variable's previously *chosen* field and sets the assigned field as *chosen*. By default, lexically the first field in the union is chosen by Conformiq Designer.

The predefined function **ischosen**(...) can be used to check if a particular field is chosen in a union variable. Note that it is a run-time error to reference a non-chosen union field.

```
union U
{
    int i;
    float f;
}

...

U u;
// No field is chosen
assert !ischosen(u.i);
assert !ischosen(u.f);

u.i = 10;

// Field 'i' is chosen and its value is 10
assert ischosen(u.i);
assert !ischosen(u.f);

u.f = 3.14;
assert !ischosen(u.i);
assert ischosen(u.f);

// Field 'f' is chosen and its value is 3.14.
// The value of field 'i' is lost.
int a = u.i;
// Run-time error occurs here!
```

The differences between QML unions and TTCN-3 or C++ unions are as follows:

- QML unions defined in CQA files may not contain anonymous inner types. However, unions defined in TTCN-3 files in compliance with TTCN-3 may be imported into the model regardless of this restriction.
- Unlike TTCN-3, QML unions cannot contain recursive definitions (inner fields of its own type).
- Unlike TTCN-3, QML unions cannot be sent or received through a port.
- Unlike C++, the fields of a QML union do not overlap in memory. An attempt to access a non-chosen field leads to a run-time error.

Template types

Structured user-defined types (classes, records and unions) may be parameterized with type arguments. A parameterized type consists of a type name (see Section Templates) name and an actual type argument list. It is a compile time error if the type name is not the name of a template class, interface, record, or union, or if the number of type arguments in the actual type argument list differs from the number of declared type parameters. Template types are further discussed in Section Templates.

4.2.6 Access Modifiers

The access to classes, records, constructors, methods and fields is regulated using access modifiers, i.e., classes and records can control what information or data is accessible by other classes and records.

public

Members declared **public** are visible to any class / record.

private

Members declared **private** are strictly controlled, meaning that they cannot be accessed from anywhere outside the enclosing class / record.

protected

Members declared **protected** in a super type can be accessed only by subtypes. Protected members cannot be accessed from anywhere outside the enclosing class / record.

By default, the members of classes are private and the members of records are public.

4.2.7 Type Aliases

Type aliases may be declared using the keyword `typedef`; it aliases an existing type whereas a variable declaration creates a new memory location. Since `typedef` is a declaration, it can

be intermingled with a variable declaration. For example

```
typedef int Integer;
Integer x = 100;
```

```
typedef SomeTemplateType<Integer> MyType;
MyType y = new MyType();
```

4.2.8 Control structures

Conditional statements

A conditional statement in the QML textual notation has the form

```
if (condition) statement
```

where the condition must be surrounded by parentheses. A more general form of the conditional statement is

```
if (condition)
    true-clause
else
    false-clause
```

The `if—else` construct may become cumbersome when there are multiple selections with many alternatives. Here it is better to use the `switch` statement which has the form

```
switch (expr)
{
    case value:
        statements;
        break; // Break or else fall through to the next case label.
    ...
    default:
        statements;
        break;
}
```

Loops

The `while` loop executes a statement while the condition is satisfied. It has the form

```
while (condition)
    statement
```

If you want to make sure that the loop is executed at least once, use the `do`—`while` loop instead. It has the form

```
do
    statement
while (condition);
```

Determinate Loops

The `for` loop is a construct that supports iteration that is controlled by a counter or similar which is updated at each iteration. The general form is

```
for (initialization-clause; condition-clause; update-clause)
    statement
```

Note that currently the QML textual notation does not support the `for-each` construct of Java 5.0.

4.2.9 Input and Output

Communication with an environment is carried out using ports. A port is a point of communication. There are three types of ports in QML:

1. Input ports
2. Output ports
3. Internal ports

An input port is a part of the external interface of the system specified in QML. It is a one-directional channel for messages that arrive to the system from the outside world (inbound data).

An output port is similar, but it is for messages that leave from the system to the outside world (outbound data).

Internal ports are used for communication between threads inside the system and they are bidirectional. They are not visible and cannot be observed from the outside world. As opposed to input and output ports, internal ports can also be created dynamically during execution. Input and output ports cannot be created dynamically because that would mean that the external, "physical" interface of the system would change unpredictably on the fly.

Note that records are the only types that can be sent to and received from ports.

An internal port is defined by instantiating `CQPort`. `CQPort` has the following definition

```
class CQPort {
     /** Build a new internal port. External ports are defined in the
         system block. */
     public CQPort();
     /** Give a descriptive name to the port. */
     public final void setPortName(String name);
     /** Send a message to an external output port or to an internal
         port.*/
     public final boolean send(AnyRecord r, float timeout);
     /** Send a message to an external output port or to an internal
         port without timeout. */
     public final boolean send(AnyRecord r);
     /** Receive a message from an external input port or from an
         internal port. */
     public final AnyRecord receive(float timeout);
     /** Receive a message from an external input port or from an
         internal port without timeout. */
     public final AnyRecord receive();
     /** A synchronous call: send and receive without a timeout. */
     public final AnyRecord sync(AnyRecord r);
}
```

If the above operations of `CQPort` timeout, `CQTimeoutException` is thrown. The definition of `CQTimeoutException` is as follows:

```
class CQTimeoutException extends Exception { }
```

External ports are, however, defined statically inside the system block discussed next. The type of an external port is also `CQPort`. It is a run-time error to send a message to an external input and/or trying to receive a message from an external output port.

Messages delivered internally via internal model ports take precedence over messages received from the external interface.

QML library contains also a convenience function for receiving a certain kind of message from an interface called `cq_receive<T>()` (ie. it is a template function parametrized with

a template type *T*). The following textual model fragment shows a very common pattern that one can observe in QML models when communicating with the environment or with other model level threads:

```
AnyRecord a = input.receive();
require a instanceof MyType;
MyType m = (MyType) a;
```

The above can be rewritten using `cq_receive<T>()` as follows:

```
MyType m = cq_receive<MyType>(input);
```

The use of `cq_receive<T>()` is encouraged in examples such as above as the analysis of `cq_receive<T>()` is less time and memory consuming for the test generation algorithm than by *requiring* that the received message is of given type.

4.2.10 System Block

The system block begins with the keyword `system`, and it is used to define external ports that are used to communicate with an environment. Inside the system block the names, directions, and types that can be sent or received, are given for each port. There can only be one system block in a model.

For example:

```
system {
    Inbound in : MyRecord, AnotherRecord;
    Outbound out : AnyRecord;
}
```

The system block above defines two ports: an input port `in` for receiving messages from an environment and an output port `out` for sending messages to an environment. The record type names after the colon (`:`) define upper boundaries for the types that can be sent or

received from a particular port. Therefore, in the example above, we may receive only instances of record type `MyRecord`, `AnotherRecord`, and their sub-types from `in`, while we may send records of any kind to port `out`, as all the user-defined record types are sub-types of `AnyRecord`.

4.2.11 Main Entry Point

In "standard Java", all the functions are methods of some class, thus a shell class for the main entry point is required. The main entry point is defined as a static method of this shell class. QML, on the other hand, has global variables and functions. In QML, the main entry point is a global method that takes no arguments and returns no value, i.e. it has the following signature

```
main: () -> void
```

For example

```
void main()
{
    ...
}
```

4.2.12 Globals and Functions

As mentioned earlier, QML supports global functions and variables, similarly as in C and C++. You may also define type aliases in the global scope. All the globals are public.

For example

```
int global = 1;
typedef int MyAlias;
MyAlias max(MyAlias a, MyAlias b) { return a > b ? a : b; }
```

4.2.13 Modifiers

Access modifiers in QML are essentially the same as in Java with the following variations:

- There is no support for `volatile`, `transient`, `strictfp`, and `native` modifiers.
- All the user-defined types are always `public`.

4.3 Object Orientation

QML is an object-oriented programming language just like Java. However, while Java is "totally" object-oriented, i.e. it is impossible to program it in the procedural style, this is not the case with QML as mentioned previously.

4.3.1 Inheritance

QML, just like Java, supports single inheritance: a structured type may only extend a single parent. Each class type is a sub-type of `Object` and each record type is a sub-type of `AnyRecord`.

For example

```
class ParentClass { ... }
class ChildClass extends ParentClass { ... }
```

```
record ParentRecord { ... }
record ChildRecord extends ParentRecord { ... }
```

4.3.2 Interfaces

An interface is an abstract type with no implementation details. Its purpose is to define how a set of classes and records will be used. Types that implement a common interface can be used interchangeably within the context of the interface type.

Essentially interfaces in QML are just like interfaces in Java: they may only contain abstract methods and static final fields. All the members of an interface are always public as opposed to Java where members are only public by default.

Note that records may not implement interfaces.

For example

```
interface MyInterface {
    public void fun();
}

class C implements MyInterface {
    public void fun() { ... }
}
```

4.3.3 Operator Overloading

Often it is a design goal of an object-oriented language that user-defined types can have all the functionality of built-in types and QML is no exception. Therefore, as opposed to Java, QML supports operator overloading which allows a more intuitive and consistent way of

operating with user-defined types.

In QML, operators are implemented as non-static methods whose return value represents the result of an operation and whose parameters are operands. The operator is thus overloaded for the particular type.

A binary operator is defined as a non-static member method taking one argument. A unary operator is defined as a non-static member method that takes no arguments, respectively. Operators are overloaded using the keyword `operator`.

For example, to overload the subtraction (`-`) operator (binary operator) in type `MyType`, define

```
public MyType operator - (MyType operand) { ... }
```

and to overload the negation (`-`) operator (unary operator), define

```
public MyType operator - () { ... }
```

The following binary operators may be overloaded in QML.

```
== != > < <= >= + - * / % += -= *= /= %=
```

The following unary operators may be overloaded in QML.

```
- ++ (prefix and postfix) -- (prefix and postfix) ~
```

4.3.4 Templates

Generics (or more accurately, templates) in QML are not implemented as in Java 5.0 by using type erasure, but rather as templates like in C++. In this regard, Java generics are very

different from QML templates: QML produces different types for each distinct template instantiation, which means that primitive types and methods may be used as template arguments also.

As QML supports global functions, it also supports function templates. Function templates provide a functional behavior that can be called for different types — in essence, a function template represents a family of functions. The following example shows a function template that returns a maximum of two values:

```
<T> T max(T a, T b) { return a > b ? a : b; }
```

Note that in Java (as well as in QML) syntax the type arguments are placed before the return type in function declaration.

Similarly to functions, also classes and records can be parameterized with types. For example

```
class MyClass<T> {
    public MyClass(T variable) { this.variable = variable; }
    public T Get() { return variable; }
    private T variable;
}

record MyRecord<T> {
    public T Get() { return variable; }
    public T variable;
}

...

// Instantiate MyClass with a primitive int.
MyClass<int> instance = new MyClass<int>(10);
assert instance.Get() == 10;

// Instantiate MyRecord with a predefined String.
MyRecord<String> rec;
rec.variable = "Conformiq";
```

As mentioned before, Conformiq Designer produces different types for each distinct

template instantiation, which means that methods may be used as template arguments also. For example

```
class MyClass { ... }
void function(MyClass r) { ... }

<T> void generic(MyClass r)
{
    T fun;
    fun(r);
}
void main()
{
    generic<function>(new MyClass());
}
```

In addition, QML supports arrays of parameterized types, which Java does not due to type erasure. Therefore it is perfectly legal to write the following code in QML while in standard Java this causes a compiler error.

```
class MyClass<T> { ... }

...

MyClass<int> array = new MyClass<int>[10];
```

4.3.5 Nullable Types

QML supports nullable types in a similar fashion to C#.

Nullable types address the scenario where you want to be able to have a value type with a null value — a nullable type can represent the normal range of values for its underlying value type, plus an additional null value. For example "nullable of Boolean" may have values `true`, `false`, or `null`.

Nullable types in QML have the following characteristics:

- Nullable types represent primitive type variables that can be assigned the value of null. A nullable type value cannot be created based on a reference type (classes and arrays) or a record type.
- Nullable types are created using syntax *T?*, where *T* is a primitive type.
- A value is assigned to a nullable value in the same way as for an ordinary primitive type.
- Checking for null values is carried out by comparing a nullable value against `null`.

For example

```
int? a = null;
int? b = 2;
assert a == null;
assert b != null;
a = 1;
assert a != null;
assert a == 1;
```

4.3.6 Implicitly Typed Local Variables

QML supports implicitly typed local variables, which permit the type of local variables to be inferred from the expressions used to initialize them. When an identifier is unbound in the local scope, the type of the variable is determined at compile time based on the expression to the right of the assignment. Implicitly typed local variables are declared with the keyword `var`.

For example

```
// x, y, z, and a are unbound here.
var x = new MyClass();
var y = 10;
var z = "string";
var a = new MyClass[10];
// x is bound to instance of MyClass here.
// y is bound to an integer.
// z is bound to a String.
// a is bound to MyClass[].
```

The above implicit typed local variable declaration is equivalent to the following.

```
MyClass x = new MyClass();
int y = 10;
String z = "string";
MyClass[] a = new MyClass[10];
```

Note that when using `var` for arrays, no brackets on the left hand side of the assignment are needed. Therefore the examples below are invalid.

```
var[] a = new MyClass[10]; // Illegal.
var a[] = new MyClass[10]; // Illegal.
```

There are a few restrictions that an implicitly typed local variable are subjected to.

- The declarator must include an initializer, i.e., the following is illegal:

```
var x; // No initializer to infer type from.
```

- Implicitly typed local variables may not be used for array initializers, i.e., the following is illegal:

```
var x = {1, 2, 3}; // Illegal.
```

- The compile-time type of the initializer expression cannot be the `null` type.

```
var x = null; // Cannot infer type of x from null.
```

- `var` can be used for local variables only.

As with any other variable declaration, the keyword `var` may be used to hide an existing binding of the given identifier:

```
int x = 100;
// x is bound to integer here.
{
    var x = "string";
    // x is bound to String here.
}
// x is bound to integer here.
```

4.4 Modeling for Test Generation

This chapter describes some constructs that are useful when modeling for test generation.

4.4.1 Modeling Combinatorial Test Data

Suppose a system model states that when a message comes in, it is forwarded out unchanged. This particular message has a number of fields, some of them integers, some strings. For some reason there is cause to suspect that the forwarding feature in the real implementation is flawed, so we would like to have a number of different message combinations to test this particular forwarding feature. However, because the model predicts that the message is forwarded in verbatim, Conformiq Designer will generate only one test for this.

The "combinatorial test data generation" support in Conformiq Designer can be used to

overcome the stated challenge. Part of the model from which Conformiq Designer is to automatically generate more data combinations is explicitly modeled in the textual modeling language by `combine_all` and `combine_allpairs` constructs as follows:

```
combine_all { ... }
combine_allpairs { ... }
```

If the "combinatorial mode" is "all" (in the case of `combine_all`), Conformiq Designer will calculate a set of all possible combinations in the region and generate a test for each combination.

If the "combinatorial mode" is "allpairs" (in case of `combine_allpairs`), Conformiq Designer will calculate a set of all data pair combinations in the region and generate a test for those cases.

For example

```
combine_all {
    require (msg.a == 1 || msg.a == 2 || msg.a == 3);
    require (msg.b == "1" || msg.b == "2" || msg.b == "3");
}
```

The above example would introduce 9 different goals that Conformiq Designer aims to cover which would allow Conformiq Designer to generate 9 different test cases to test all 9 combinations. Note that without the `combine_all` block, Conformiq Designer would have 3 atomic condition goals to cover in the first require statement and another 3 in the latter one, all of which can be tested in just 3 test cases.

Note that the `belongs_to` construct (which is used to eliminate state space branching inside require statements that Conformiq Designer needs to perform when analyzing the model) will not cause Conformiq Designer to generate data combinations. When more data combinations are needed, the Boolean `||` operator

should be used instead.

`combine_allpairs` works similarly but it will generate a new goal for each new pair in the region.

Technically, the combinatorial test data generation support generates various data combinations by combining the covered "Conditional Branch" and "Atomic Condition Branch" structural features: in the example above the combinations would be *{msg.a == 1, msg.b == "1"}*, *{msg.a == 1, msg.b == "2"}*, ..., *{msg.a == 3, msg.b == "3"}*. Note that the selection of "standard coverage goals" defined using Coverage Editor is irrelevant for constructs used inside a combinatorial region. Therefore, in the example above, Conformiq Designer will generate 9 different data combinations even if the "Atomic Condition Coverage" option was not enabled in the Coverage Editor.

4.4.2 Model Regions

Model regions are used to identify special parts of the behavior, for example, related to system configuration for which Conformiq Designer aims to design functional tests for not just one but all feasible system configuration parameter settings.

Coverage targets, or *checkpoints* in Conformiq nomenclature, in the model are normally ”singular” in the sense that they are considered covered as soon as there is one execution through the model that passes the checkpoint. This means that if a method in the model has a requirement, this requirement is “done with” as soon as it’s covered through one invocation of the method (potentially out of many). But sometimes it’s desirable to see these requirements at the model level being “multiplied” across the different invocations of the method. (Refer to Section Test Case Selection in Conformiq for more information about coverage guided test generation and test selection). For example:

```
void processX(X x)
{
    processCommonFieldA(x);
    processCommonFieldB(x);
    // X-specific model part
}
void processY(Y y)
{
    processCommonFieldA(y);
    processCommonFieldB(y);
    // Y-specific model part
}
```

The `processCommon...` methods above contain a set of checkpoints for statements, branches, etc. but as soon as the they are handled e.g. in `processX` method, Conformiq Designer considers that the checkpoints have been covered and would not attempt to cover them again when `processY` method is invoked. Ultimately, a number of test cases are generated for verifying `processX` but for `processY` it could be that Conformiq Designer would only generate test cases for the "Y specific" model constructs.

In order to guide Conformiq Designer to produce tests for verifying parameter checking functionality in the example above, QML modeling language includes a construct for explicitly marking the model parts that involve the parameter checking functionality via following predefined functions:

```
void cq_begin_region(String name_of_the_region);
void cq_end_region();
```

`cq_begin_region`, as the name suggests, signals a beginning of a model region that has a specific name. `cq_end_region()` is used to signal the end of the region, respectively. Technically the constructs work so that the coverage targets are duplicated for each new encountered model region.

Note that the argument to the `cq_begin_region` cannot be *dynamic* ie the value cannot directly depend on external input.

So to make sure in the above example that the tests in fact perform checks for all the necessary input data, the model could be updated as follows

```
void processX(X x)
{
    cq_begin_region("Region for X");
    processCommonFieldA(x);
    processCommonFieldB(x);
    cq_end_region();
    // X-specific model part
}
void processY(Y y)
{
    cq_begin_region("Region for Y");
    processCommonFieldA(y);
    processCommonFieldB(y);
    cq_end_region();
    // Y-specific model part
}
```

4.4.3 Regions with No Coverage Goals

QML provides a construct for marking areas in the model that have no coverage goals attached to them. These regions are marked using the `nocoverage` keyword.

For example:

```
nocoverage
{
    // There will be no coverage goals for constructs in this block.
    if (x == 10)
    {
        foo();
    }
}
```

In the above example, there will be no conditional branching or statement coverage goals for the *if* statement and no statement coverage goals for the method invocation.

However, if a *nocoverage* block contains a *requirement* statement, the given requirement will be treated as a coverage goal and Conformiq Designer strives to find an execution that covers that given requirement.

4.4.4 Scenario and Narrative

The QML language has two constructs that can be used to give meaningful names to the generated test cases:

```
scenario <string expression>;
narrative <string expression>;
```

Here <string expression> is a concatenation of string and numeric values, e.g., "foo" + a + i where "foo" is literal, 'a' is a string variable and 'i' is an integer variable. The evaluation of <string expression> cannot have any side effects, therefore for example, function calls are not allowed in <string expression>. Both these constructs are "comments" in nature and do not affect test generation.

See Section Intelligent Test Case Naming for more information about intelligent test case naming and use of *scenario* and *narrative* tags.

4.5 Predefined Data Types

QML includes a number of predefined data types that can be used in models.

4.5.1 Class and Record Super Types

`Object` is the super type of all the class types.

```
abstract class Object {
    /** Return the string representation of the object. */
    public String toString();
    /** Creates and returns a copy of this object. */
    public Object clone();
}
```

`AnyRecord` is the super type of all the record types.

```
record AnyRecord { }
```

4.5.2 Threads and Communication

`CQPort` is the class that can be used to communicate with an environment and between multiple threads. An operation which takes a timeout argument throws a `CQTimeoutException` if a timeout occurs. If the timeout argument is set below 0, then the particular operation never makes a timeout.

```
class CQPort {
    /** Build a new internal port. External ports are defined in the
        system block. */
    public CQPort();
    /** Give a descriptive name to the port. */
    public final void setPortName(String name);
    /** Send a message to an external output port or to an internal
        port.*/
    public final boolean send(AnyRecord r, float timeout);
    /** Send a message to an external output port or to an internal
        port without timeout. */
    public final boolean send(AnyRecord r);
    /** Receive a message from an external input port or from an
        internal port. */
    public final AnyRecord receive(float timeout);
    /** Receive a message from an external input port or from an
        internal port without timeout. */
    public final AnyRecord receive();
    /** A synchronous call: send and receive without a timeout. */
    public final AnyRecord sync(AnyRecord r);
}
```

`Runnable` is an interface that each class whose instances are intended to be executed as threads must implement. The class must define a method of no arguments called `run()`. This interface is designed to provide a common protocol for objects that wish to execute code while they are active.

```
interface Runnable {
    public void run();
}
```

`Thread` is a thread of execution in a program. Conformiq allows having multiple threads of execution running concurrently.

```
class Thread {
    public Thread(Runnable runnable);
    /** Causes this thread to begin execution and the run()
        method of this thread is called and set a descriptive name
        to the thread via name parameter. */
    public final void start(String name);
    /** Starting the thread causes the object's run() method
        to be called in that separately executing thread. */
    public void run();
}
```

Like in Java, there are two ways to create a new thread of execution in QML. One is to declare a class to be a subclass of `Thread`. This subclass should override the `run` method of `Thread`. An instance of the subclass can then be allocated and started. For example

```
class MyThread extends Thread {
    public void run() { ... }
}
...
MyThread t = new MyThread();
t.start("MyThread");
```

The other way is to declare a class that implements the `Runnable` interface described above. That particular class must implement the `run` method. An instance of the class can then be allocated, passed as an argument when creating `Thread`, and started. For example

```
class MyThread implements Runnable {
    public void run() { ... }
}
...
Thread t = new Thread(new MyThread());
t.start("MyThread");
```

`StateMachine` provides the means to construct a "state machine" — a state machine has its own execution thread, and it supports communication with it using ports (see Section Input and Output).

```
abstract class StateMachine extends CQPort implements Runnable {
    /** Causes this state machine to begin execution and initial state of the
        corresponding state machine is called (or the run() method
        if there is no such a state machine diagram) and set a descriptive name
        to the state machine via name parameter. */
    public final void start(String name);
}
```

`setThreadName(String name)` and `start()` are deprecated in Conformiq Qtronic 2.1 and should not be used. Instead the state machine should be started via a call to `start(String name)` which sets the name to the state machine instance before starting the actual state machine execution.

There are two ways to create state machines. One is to declare a class that extends `StateMachine` and implement `run` in this class using the QML textual notation. For example

```
class MyStateMachine extends StateMachine {
    public void run() { /* State machine execution logic here. */ }
}
```

Once defined, instances of the state machine may be started.

The other way to create a state machine is to declare a class that extends `StateMachine` and define a state machine diagram using **Conformiq Modeler** with the same name as the declared class. This state machine diagram defines the run method using the QML graphical notation. This is further discussed in Section Graphical Notation of QML.

4.5.3 Exceptions

The `Throwable` class is the super class of errors and exceptions. As opposed to Java, QML does not require that only objects that are instances of this class (or one of its subclasses) be thrown.

```
class Throwable { }
class Exception extends Throwable { }
```

`CQTimeoutException` is the exception that the operations on `CQPort` throw when a timeout occurs.

```
class CQTimeoutException extends Exception { }
```

4.5.4 Synchronization

`Lock` enables controlling access to a shared resource by multiple threads: only one thread at a time can acquire the lock, and the resource cannot be accessed without the lock.

```
class Lock {
    public Lock();
    /** Acquire the lock. */
    public void lock();
    /** Release the lock. */
    public void unlock();
}
```

`Semaphore` is a lock which can be acquired for a certain number of times before blocking. The value of the semaphore is initialized by the number of equivalent shared resources it is intended to control. Each call to `acquire` blocks if necessary until a resource is available, and then takes it. Each call to `release` adds to the number of shared resources, potentially releasing a blocking acquirer.

```
class Semaphore {
     /** Initialize to the number of shared resources. */
     public Semaphore(int value);
     /** Acquires the semaphore, blocking until it is available. */
     public void acquire();
     /** Release the semaphore. */
     public void release();
}
```

`Barrier` can be utilized in synchronizing threads. A thread executing an "episode" of a barrier waits for all other threads before proceeding to the next. When a barrier is reached, all threads are forced to wait for the last thread to arrive.

```
class Barrier {
      /** Initialize to the number of waiting threads. */
      public Barrier(int value);
      /** Wait until a number of threads have reached the barrier. */
      public void await();
}
```

4.5.5 Containers

The `Comparable<T>` interface imposes a total ordering of the objects in each class that implements it.

```
interface Comparable<T> {
    public boolean comp(T value);
}
```

The `Pair` as used in Lisp-like languages is used to keep pairs of values.

```
class Pair<First, Second> {
    public Pair();
    public Pair(First first, Second second);
    public First first;
    public Second second;
}
```

The `Enumeration<T>` is an interface for generating a series of elements, one at a time. Successive calls to the `nextElement` method return successive elements of the series. In order to use `Enumeration`, you must include the line `import conformiq.Enumeration;`.

```
interface Enumeration<T> {
    /** Tests if this enumeration contains more elements. */
    public boolean hasMoreElements();
    /** Returns the next element of this enumeration if this enumeration
        object has at least one more element to provide. */
    public T nextElement();
}
```

The `Vector<T>` is a dynamic array of objects. In order to use `Vector`, you must include the line `import conformiq.Vector;`.

```
class Vector<T> {
     /** Create an empty vector. */
     public Vector();
     /** Appends the specified element to the end of this vector. */
     public void add(T value);
     /** Tests if the specified object is a component in this
         vector. */
     public boolean contains(T value);
     /** Returns the component at the specified index. */
     public T elementAt(int index);
     /** Returns an enumeration of the components of this vector. */
     public Enumeration<T> elements()
     /** Returns the component at the specified index. */
     public T get(int index);
     /** Replaces the element at the specified position in this
         Vector with the specified element. */
     public T set(int index, T value);
     /** Removes the element at the specified position in this Vector. */
     public void remove(int index);
     /** Is this an empty vector. */
     public boolean isEmpty();
     /** Returns the number of elements in the vector. */
     public int size();
     /** Removes all of the elements from this vector. */
     public void clear();
}
```

The `Stack` class represents a last-in-first-out (LIFO) stack of objects. `Stack` in QML, as opposed to `Stack` in standard Java, does extend `Vector`, which means that stack in QML is strictly LIFO. In order to use `Stack`, you must include the line `import conformiq.Stack;`.

```
class Stack<T> {
    /** Create an empty stack. */
    public Stack();
    /** Tests if this stack is empty. */
    public boolean empty();
    /** Looks at the object at the top of this stack without removing it from
        the stack. */
    public T peek();
    /** Removes the object at the top of this stack and returns that object as
        the value of this function. */
    public T pop();
    /** Pushes an item onto the top of this stack. */
    public T push(T item);
    /** Returns the 1-based position where an object is on this stack. */
    public int search(T value);
}
```

The `Hashtable<Key, Value>` maps keys to values. Note that *Value* must be a nullable type (i.e. a type that can be assigned a `null` value. See Sections Reference Types and Nullable Types for details). In order to use `Hashtable`, you must include the line `import conformiq.Hashtable;`.

```
class Hashtable<Key, Value> {
    /** Creates an empty hashtable. */
    public Hashtable();
    /** Clears this hashtable so that it contains no keys. */
    public void clear();
    /** Tests if some key maps into the specified value in this hashtable. */
    public boolean contains(Value value);
    /** Tests if the specified object is a key in this hashtable. */
    public boolean containsKey(Key key);
    /** Returns true if this Hashtable maps one or more keys to this value. */
    public boolean containsValue(Value value);
    /** Returns an enumeration of the values in this hashtable. */
    public Enumeration<Value> elements();
    /** Returns the value to which the specified key is mapped in this
        hashtable. */
    public Value get(Key key);
    /** Tests if this hashtable maps no keys to values. */
    public boolean isEmpty();
    /** Returns an enumeration of the keys in this hashtable. */
    public Enumeration<Key> keys();
    /** Maps the specified key to the specified value in this hashtable. */
    public void put(Key key, Value value);
    /** Removes the key (and its corresponding value) from this hashtable. */
    public void remove(Key key);
    /** Returns the number of keys in this hashtable. */
    public int size();
}
```

The `Queue` class (introduced in Conformiq tool suite 4.4.0) order elements in a FIFO (first-in-first-out) manner. `Queue` in QML, as opposed to `Queue` in standard Java is not an interface but a concrete container class. In order to use `Queue`, you must include the line `import conformiq.Queue;`.

```
class Queue<T> {
     /** The default constructor that creates an empty queue. */
     public Queue();
     /** Tests if this queue is empty. */
     public boolean isEmpty();
     /** Retrieves, but does not remove, the head of this queue. It is an error
         to call this routine if the queue is empty. */
     public T element();
     /** Retrieves and removes the head of this queue. It is an error
         to call this routine if the queue is empty. */
     public T remove();
     /** Pushes an item onto the top of this queue. */
     public boolean add(T item)
     /** Returns the number of elements in this queue. */
     public int size();
}
```

4.6 Predefined Functions

QML includes a number of predefined functions that can be used in models.

4.6.1 Assertion Like Functions

`assert` checks that the boolean argument supplied is `true`. An assertion is a predicate placed in the model to indicate that the predicate is expected to be always true at that point. If `assert` is called with a `false` argument, a run-time error is signaled.

```
assert <expression>;
```

`require` checks that the boolean argument supplied is `true`. In Conformiq Designer, it is guaranteed that `require` is never called with a `false` argument — an attempt to call require with a `false` argument triggers a backtracking point.

```
require <expression>;
```

It is important to note the semantic difference between `assert` and `require`. `assert` is used to assert that expression provided is true. Assertions should be used to document logically "impossible" situations and discover modeling errors. A failed assertion means that the (calling) program is fundamentally wrong thus *internally inconsistent*. `require`, on the other hand, is used to require that the expression provided is true. A failed requirement means that a series of nondeterministic choices and environment inputs as a whole have led to a situation that is beyond the scope of the program, especially when the program is considered to be a description or a specification of the system. In brief, `assert`s are used to make sure that the program is internally consistent while `require`s are used to *restrict* nondeterministic choices and environment inputs that are inferred by Conformiq Designer.

As of Conformiq Designer version 4.2.0, the tool detects and reports a set *{ Req1 ... ReqN }* of `require` statements (i.e., the syntactical lines) as "possibly conflicting" if, during the test generation, at least one execution was found that goes through all the `require` statements *Req1 ... ReqN* (in any order, possibly with repetitions) but was terminated due to an unsatisfiable statement in *Req1 ... ReqN*, and no execution was found that would have gone through all the `require` statements *Req1 ... ReqN* (in any order, possibly with repetitions) without having been terminated due to an unsatisfiable statement in *Req1 ... ReqN*.

See Section Using require to Limit the Search Space for details about how to use `require` in optimizing the models for test generation.

`notreached` marks a code block that is never reached. In Conformiq Designer, it is guaranteed that `notreached` is never called — an attempt to call `notreached` triggers a backtracking point in a similar way as does an attempt to call `require` with a `false` argument. `notreached()` is equivalent to `require(false)`.

```
void notreached();
```

4.6.2 Query Functions for Fields of Structured Types

`ispresent` returns true if the given argument is present (not omitted) and false otherwise. The compiler will report an error if the given argument is not of the Optional<T> type.

```
boolean ispresent<T>(T field);
```

`ischosen` returns true if the given argument is a reference to a *chosen* field of a union and false otherwise. The compiler will report an error if the given argument is not a reference to a field of a union.

```
boolean ischosen<T>(T field);
```

4.6.3 Requirements

In addition to the different coverage criteria based on the structure of the model, the user has the option to use requirement traceability links to establish new test goals driven by *functional requirements*. The requirement links are marked in the model by the `requirement` statement. As described in the Testing with Conformiq chapter, functional requirements inserted using the `requirement` statement are used as coverage criteria that can be enabled and disabled independently in the Conformiq Eclipse Client user interface. Every selected requirement becomes a test goal that guides Conformiq Designer to look for behaviors that cover the particular requirement. A test case covers a selected requirement if executing the test case against the model causes a requirement statement that has the selected requirement as the argument to be executed.

```
requirement <constant string>
```

The argument to the `requirement` statement defines the requirement identifier and must be a globally unique constant string. Conformiq Designer model import gives an error if the model contains more than one requirement sharing the same identifier.

For example:

```
requirement "Here we have fulfilled a functional requirement X";
```

Functional requirements are hierarchical and the `/` character is used to separate hierarchical requirements. For example

```
requirement "Top level/Here we have fulfilled a functional requirement Y";
```

Often functional requirements contain a unique name or an identifier and a brief summary with possibly some rationale for the requirement. This information is used to help to understand why the requirement is needed and to track the requirement through the development process. In order to accommodate this, a summary or a description can be given as an argument to the `requirement` statement using the following syntax

```
requirement <constant string> : <constant string>;
```

The first argument to the `requirement` statement defines the globally unique identifier as before. The second argument gives the summary or more detailed description of the functional requirement. The summary part does not need to be globally unique like the identifier part. For example

```
requirement "This is an identifier" :
    "This is a summary of the functional requirement";
```

4.6.4 Mathematical Functions

`ceiling` returns the smallest integer greater than or equal to the specified value.

```
int ceiling(double value);
```

`floor` returns the largest integer less than or equal to the specified value.

```
int floor(double value);
```

`abs` returns the absolute value of a specified value.

```
double abs(double value);
int abs(int value);
```

4.6.5 Probabilities and Priorities

Keywords `probability` and `priority` make it possible to experiment with adding probabilities and/or priorities to models. This mechanism can be used to simulate both use case probability modeling and general priority schemes in a robust fashion.

```
probability <expression>
priority <expression>
```

The <expression> must always be positive. For `probability` the most sensible values are between 0 and 1. For `priority` any positive number can be used.

Conformiq Designer calculates for every generated "path" in the model a "priority value" in the following fashion: at the beginning of the model the "priority value" is set to 1. Every "probability N" changes the priority number from *x* to *x*N*, and every "priority N" changes it from *x* to *x+N*. Thus, the "priority value" after executing

```
probability 0.5
priority 2
probability 0.5
```

is *((1 * 0.5) + 2) * 0.5 = 1.25*.

As detailed in Section Test Case Selection in Conformiq, Conformiq Designer tries to cover each target test goal with lowest cost possible, i.e., it always prefers covering a test goal when the cost of covering it is lower than what it was earlier. This cost is defined in terms of external input events and timeouts so that covering a test goal after 3 external inputs is "cheaper" than covering it after 4 external input events. When priorities and probabilities are used, the cost is a combination of the number of external input and timeout events and the "priority mass" described above. This allows the user to prefer certain behaviors over others by carefully placing priorities and probabilities in the model. In addition, when Conformiq Designer has finished enumerating test cases, it calculates a probability for each of them by dividing the priority value of the test case with the sum of all the priority values. Conformiq Designer reports the test cases in the order of decreasing probability, if these constructs are applied in the model.

Note that the behavior of the `priority` and `probability` has been extended in Conformiq Designer 4.4.1 as described above as the "priority mass", not only used to report test cases in their probability order, but also can be used to guide the test generation algorithm itself to indicate which model parts are intuitively more important and interesting than others.

To emulate use case probability modeling, use only `probability` and whenever you add a probability on one branch of the model, add probability statements on others also and make

sure they sum to one. E.g.:

```
if (msg.x < 100)
{
    probability 0.6;
    ...
}
else
{
     probability 0.4;
    ...
}
```

You can of course use `probability` on transitions also.

To use a more ad hoc priority scheme, you can emphasize different parts, functions or options in your model by adding priority bonuses to them, for example:

```
if (msg.x == 0)
{
    // important case
    priority 100;
    ...
}
```

which would make the control flows with *msg.x == 0* a hundred times as probable than the others if there were no other `priority` or `probability` statements in the model.

Finally, you can combine these two mechanisms, e.g., by using the `probability` statement between state transitions and `priority` to fine-tune priorities inside transitions. Note that for this mechanism to work well, you should use small priority values (< 1).

Being able to order test cases by their "importance" or "probability" can be very useful, but for larger models it may become very difficult to "optimize" or "tune" the model correctly. Eventually the reason to use Conformiq Designer is to improve your testing and the quality of your system under test, not to construct a test suite that looks perfect to the human eye.

For the best results, combine this feature with "all paths" generation. This will provide you

with an extensive test suite with test cases in their priority order.

Even though Conformiq Designer generates the whole test suite, in order to speed up test execution, you can execute the "most probable" test cases only, for example until the cumulative probability has reached 75% or 90%.

4.6.6 End Conditions for Test Generation

In some cases it is convenient to generate only test cases that end the system in a "clean" state meaning that Conformiq Designer will only accept test cases to the generated test suite that cause all threads in the model to be in the "clean" state or outside of "incomplete regions".

The QML language provides constructs that you can use to mark incomplete regions of the model where test generation is not allowed to end, even though Conformiq Designer would have already generated another test that covers the given continuation, but instead test generation will extend tests so that they reach all the way to the end of a given region.

These incomplete regions in the model can be marked using `incomplete` and `complete` expressions that take no parameters:

```
incomplete
complete
```

With these constructs, Conformiq Designer maintains a counter for a set of incomplete regions, rather than an "incomplete" flag of a single region and in this way the usage somewhat resembles the usage of counting semaphores.

These constructs are complementary to the 'Only Finalized Runs' test generation parameter (see Chapter Testing with Conformiq for more information) and provide more control and flexibility to test generation.

For example:

```
// An incomplete region starts here.
incomplete;

// Test generation is not allowed to stop here,
// because we are inside an incomplete region.

while (some condition)
{
    // Do some external I/O here, for example.
}

// The incomplete region ends here.
complete;

// Test generation is allowed to stop here,
// because we are not inside an incomplete region.
```

4.6.7 Miscellaneous Functions

`trace` is used to display messages in the Console View window of Conformiq Eclipse Client while testing. The primary use of `trace()` is to carry out ad-hoc *printf debugging* known to many programmers. With `trace()` you can collect some very elementary information about how the test generation progresses, for example. However, it is highly recommended to use more elegant and advanced model debugging capabilities provided by the Conformiq Model Debugger (see Section Analyzing Model Defects for more information) to analysis and debugging of the system model itself.

```
void trace(String msg);
```

As described in Section How to Configure Global Testing Parameters, *Lookahead Depth* is used to control the "search depth" or amount of work the Conformiq Designer needs to carry out for planning the tests. The lookahead depth value set in Conformiq project settings is global and affects the test generation globally. In the QML modeling language there is a construct called `cq_increase_lookahead` that is used to increase the amount of

lookahead temporarily; the function is given integral value as an argument which is added to the global *Lookahead Depth* value set in the Conformiq project settings and takes effect locally on the path being analyzed by the tool. The construct is useful when there are areas in the model that are not covered by the Conformiq Designer with the current Lookahead depth value, increase of the global Lookahead Depth value has too big of an impact to the test generation time, and it is relatively well understood by the engineer that which parts of the model require the bigger lookahead value.

```
void cq_increase_lookahead(int increment);
```

`cq_increase_lookahead` accepts strictly positive integral values as argument that are not dynamic (i.e. they do not depend on the external input to the system). Values less than 1 in addition to dynamic values are not considered by the test generation engine and a warning message will be presented to the user.

`time` returns the time that has elapsed since the testing started.

```
double time();
```

`sleep` puts the current thread to sleep for the specified amount of time in seconds.

```
void sleep(double timeout);
```

4.7 Graphical Notation of QML

In addition to a pure textual notation, QML also has a graphical notation that can be used to create design models. The graphical notation is always used with the textual notation.

4.7.1 State Machines

Recall from the earlier sections that the predefined abstract base class `StateMachine`

provides the means to construct a "state machine". A state machine has its own execution thread and it supports communication with it using ports.

There are two ways to create state machines. One is to declare a class that extends the `StateMachine` class and implement the `run` method in this class using the QML textual notation. For example

```
class MyStateMachine extends StateMachine {
    public void run() { /* State machine execution logic here. */ }
}
```

Once defined, instances of the state machine may be started. State machine threads are created like any other thread in QML, i.e., a state machine is instantiated and it is started by invoking the `start` method. (Alternatively, you can create a new instance of `Thread` by passing the state machine as an argument and call `start`.)

```
MyStateMachine sm = new MyStateMachine();
sm.start();
```

The other way is to extend the predefined `StateMachine` super class of QML as usual without providing an implementation of the `run` method in the QML textual notation. Instead, the definition of the `run` method is given as a UML state diagram that has the same name as the user-defined state machine class.

For example, assume the following

```
class MyStateMachine extends StateMachine {
    /* No run() defined here. It will be defined in a state machine
       called 'MyStateMachine'. */
}
```

Once the state machine in the QML graphical notation with the name `MyStateMachine` is provided, the state machine is taken as the `run` method.

Note that if the `run` method is defined using state machine diagrams, the state machine type may not be parameterized with type arguments. This would mean that the compiler would have to instantiate the whole state machine diagram for each distinct type argument, and this is currently not supported. Therefore, the following causes a compilation error.

```
/* Erroneous state machine declaration. */
class MyStateMachine<T> extends StateMachine { }
```

4.7.2 Transition Strings

Transition strings are used in state machine diagrams to attribute transitions. They may have the following three parts:

- trigger
- guard
- action

The parts are not obligatory, that is, an empty transition string is also valid. If a transition string contains any combination of a trigger, a guard, and an action, they have to be in the above order.

A trigger specifies the pattern of data to match and receive incoming data, while a guard specifies a condition for the transition to fire. An action, in turn, specifies the action statements to perform if the transition fires.

```
<trigger>? ('[' <guard> ']')? ('/' <action>)?
```

Trigger

A *signal trigger* is used to model the reception of an event.

An event name specifies the event that triggers a transition. The message received may be of

the exact same type as we are expecting or any of its sub-types. Recall that the type of the message must be one of the user-defined record types or `AnyRecord`. Even though state machines may not be parameterized with type arguments (see Section State Machines), the message type may be a template record. In this case the message signature must contain a proper instantiation of the template type. There is an example of this at the end of this Section.

The event signature is as follows:

```
<message type>
```

When a trigger is defined as above, all the input ports defined in the model are listened in addition to the internal port of the state machine containing the transition.

Signal triggers may also specify a singleton port which is being listened to. In this case, the trigger is composed of two parts separated by a colon (`:`). The first part defines the name of the port from which we expect a message to arrive, and the second part defines the type of the message that we expect. The port name in a trigger must be defined inside the system block as an input port, or it may be `this` in which case the internal port associated with the state machine holding the transition is used.

```
<port name>:<message type>
```

```
this:<message type>
```

If more than one thread is waiting for input to arrive from a certain port, it is unspecified which thread consumes the message.

Note that the implicit consumption of events may be turned on and off from "QML Model Coverage Settings" in Conformiq Eclipse Client user interface.

The received message is automatically bound to a local variable `msg` which is visible inside

the guard and the action parts. Note that the local variable `msg` is constant in the guard, but mutable in the action part.

Timers can be specified with the help of an `after` trigger. If none of the other triggers fire in the current state within the specified timeout interval, `after` will. A timer is initialized only when a state with a leaving transition having an after is entered. If such a state contains a hierarchy, none of the firings of the transitions that take place within the hierarchy reset the timer.

```
after(float timeout)
```

where `timeout` is the time specifier in seconds.

If a signal is received at the exact same moment when a timer timeouts, the message is handled first, i.e. message events take precedence over timeout events. Messages delivered internally via internal model ports take precedence over messages received from the external interface.

Guard

Guard expressions are simply enclosed in square brackets: `[...]`. The order in which guards are evaluated is non-deterministic in case a trigger enables more than one transition. The `else` guard can be used for a single outgoing transition to indicate that it should be fired if all other guards fail.

```
[else]
```

Action

When an event is received and a guard yields true, the transition fires and the action is

executed. An action contains a block of QML code. It always starts with the `/` character, which separates it from the other elements of the transition string. An empty action string denoted by `/` is valid.

An Example

For example, assume that we have the following QML textual notation definitions.

```
system {
    Inbound MyInput : MyRecord;
    Outbound MyOutput : MyRecord;
}
record MyRecord {
    public int x;
}
record TemplateRecord<T> {
    public T x;
}
```

Now assume that we are expecting a message of type `MyRecord` from input port `MyInput` with the member variable `x` assigned to 3.

```
MyPort:MyRecord [msg.x == 3]
/
/* Echo 'msg' back to the environment. */
MyOutput.send(msg, -1);
```

A proper template instantiation in the transition string for `TemplateRecord` would for example be

```
MyPort:TemplateRecord<String> [msg.x == "a message"]
```

4.7.3 Internal Transitions of a State

A UML level basic state may contain a set of *internal transitions*.

An internal transition is a transition that remains within a single state rather than a transition that involves two states. It represents the occurrence of an event that does not cause a change of state.

Note that an internal transition is not equivalent to a *self-transition* from a state back to the same state. If there is a sub state machine in a basic state, the self-transition causes the initial state to be entered, whereas the internal transition does not cause a change of state (including a sub state).

Internal transitions are written into the basic state as transition strings with a mandatory trigger, i.e.

```
<trigger>{1} ('[' <guard> ']')? ('/' <action>)?
```

For example:

```
input:EventX [msg.param == 1] / { output.send(msg); }
input:EventY [msg.param == 2] / { output.send(msg); }
```

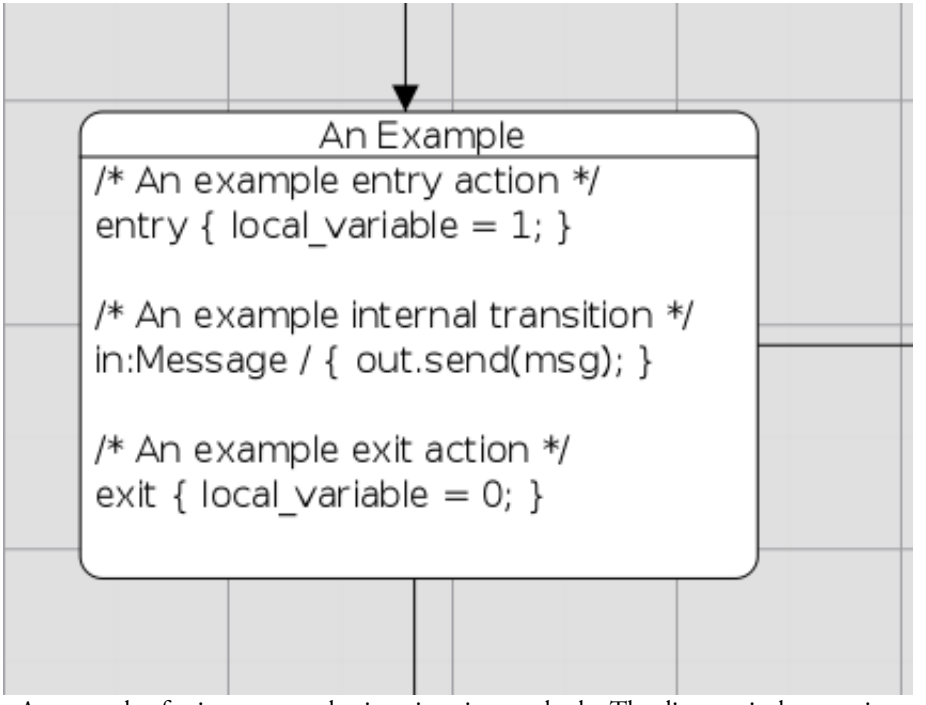
4.7.4 Entry and Exit Actions

A UML level basic state may also contain zero or one "entry actions" and zero or one "exit actions". These actions are simply a sequence of QML level statements that are executed when the state is entered (in case of an entry action) and exited (in case of an exit action). These actions are defined in the state body where also the internal transitions are defined as

follows:

```
entry <stmt>
exit <stmt>
```

For example:


An Example
/* An example entry action */
entry { local_variable = 1; }
/* An example internal transition */
in:Message / { out.send(msg); }
/* An example exit action */
exit { local_variable = 0; }

An example of using entry and exit actions in state body. The diagram is drawn using Conformiq Modeler.

4.7.5 Including State Charts

Conformiq Designer model importer supports "fragment" state chart files where the

implementation of a single state chart can be split in to multiple files. This fragment files can then be included by applying a special "include" construct introduced in Conformiq Designer 4.3.0. The main benefit of this feature is that an engineering team can distribute the work of modeling a state chart over multiple engineers who can work with their individual files, without being for example concerned that there may be conflicts introduced when they commit their work to version control system as multiple team members are contributing to a single state chart.

When you wish to add a sub state machine to a state (i.e. you want to expand the state with a sub state machine), but you also want to implement the state chart in another XMI file, you annotate the state body with an "include" statement by supplying the name of the file that contains the state chart as an argument to it. So for example, if you have a basic state and you wish to include a state chart to it which has been defined in file called "my_statechart.xmi", you would write the following to the state body

```
include "my_statechart.xmi"
```

By saying "include" in a state body, the model importer of Conformiq Designer will read in the file name and copies the state chart structure to the given state. Effectively you achieve exactly the same thing as you would by expanding the given state and implementing the sub state machine there.

There are following considerations when using the feature:

1. You can have in the same state body also internal transitions + entry and exit actions as normally.
2. You can have only one include statement in a state body; having more than one is an error. You cannot include a state chart if you have already implemented a sub state machine using "expand"
3. You are not allowed to define recursive includes, therefore if file "A.xmi" includes file "B.xmi" in one of its states, then you cannot include "A.xmi" in states defined in "B.xmi"

4. include statement must be the only statement in a given line inside a state body so if you include a state chart in a state body, the line that contains the include statement may not contain any other statements, etc. This is a limitation of the current implementation.

5. The file that you use in include statement can contain exactly one top level state charts. Having 0 or more than 1 is an error. The name of the top level state chart is not considerd at all and you can call it whatever you want. It will be translated so that the state chart there will have the same name as the state to which you include the state chart.

4.8 Examples

4.8.1 A Simple Echo Model

This example uses only the QML textual notation. The echo model (*echo.cqa*) is given below:

```
system
{
    Outbound output : Msg;
    Inbound input : Msg;
}
record Msg
{
    public String msg;
}
void main()
{
    int idx = 0;
    while (true)
    {
        String str = "message" + ++idx;
        AnyRecord recv = input.receive();
        // Require that the received message is of the type 'Msg'.
        require recv instanceof Msg;
        Msg echoed = (Msg) recv;
        // Require that the 'msg' field is what we expect.
        require echoed.msg == str;
        output.send(recv, -1);
    }
}
```

4.8.2 Another Echo Model

Here is another simple echo model. Here we use the QML textual notation to define "an echo state machine".

We start by defining the set of external ports that we require in the system block and extend the abstract base class `StateMachine` and define `EchoMachine`. The `run` method is used to define the state machine behavior in the QML textual notation.

We also define the main entry point in which we create an instance of `EchoMachine` and we start it as a new thread.

```
system {
    Outbound output : Msg;
    Inbound input : Msg;
}
record Msg {
    public String msg;
}
class EchoMachine extends StateMachine {
    public void run()
    {
        int idx = 0;
        while (true)
        {
            String str = "message" + ++idx;
            var recv = input.receive();
            require recv instanceof Msg;
            Msg echoed = (Msg) recv;
            require echoed.msg == str;
            output.send(recv, -1);
        }
    }
}
void main()
{
    EchoMachine echoer = new EchoMachine();
    echoer.start("echo machine");
}
```

4.8.3 Yet Another Echo Model

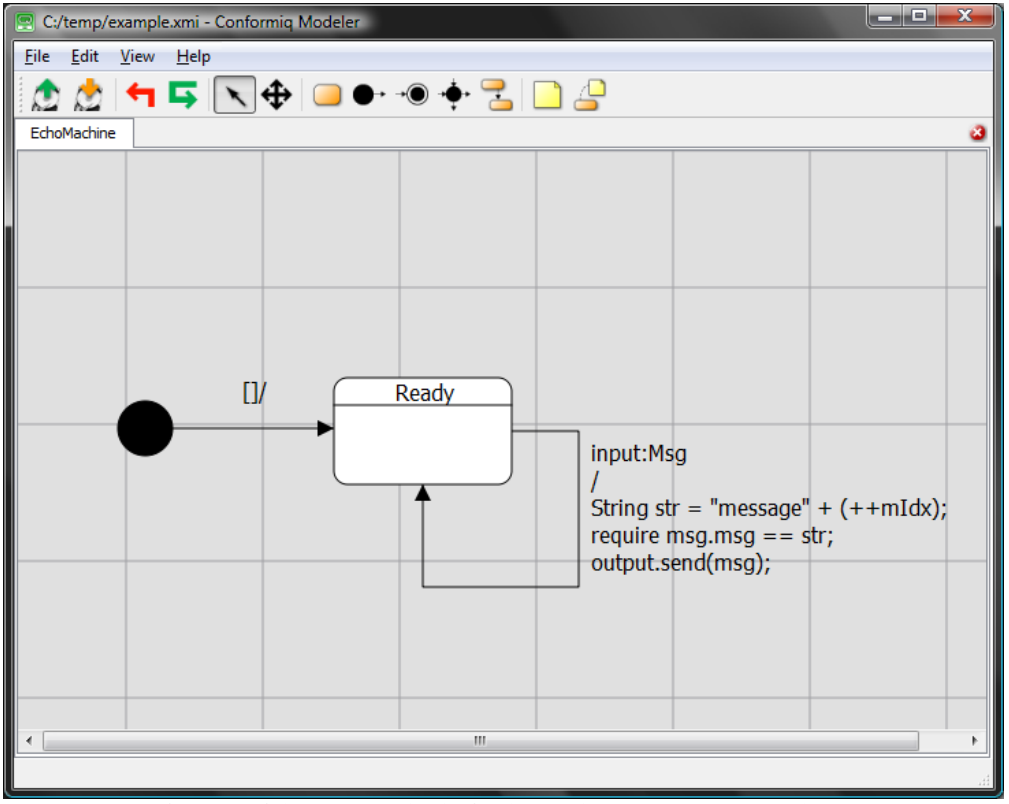
Here is yet another simple echo model. Here we use the QML graphical notation in addition to the purely textual notation and define the echo behavior in a UML state machine.

First we define the set of external ports that we require in the system block and extend the abstract base class `StateMachine` and define `EchoMachine` with a single member variable `mIdx`. We also define the main entry point in which we create an instance of `EchoMachine`, and we start it as a new thread. Note that we do not define the `run` method in `EchoMachine` using the textual notation as we are going to use the graphical notation for that.

The QML textual notation part of the echo model is shown below.

```
system {
    Outbound output : Msg;
    Inbound input : Msg;
}
record Msg {
    public String msg;
}
class EchoMachine extends StateMachine {
    private int mIdx = 0;
}
void main()
{
    EchoMachine echoer = new EchoMachine();
    Thread thread = new Thread(echoer);
    thread.start("echo");
}
```

The behavior of the state machine is defined using **Conformiq Modeler** as shown in the figure below.



Definition of the `run` method of EchoMachine as a UML state diagram

4.9 Importing TTCN-3 Type Definitions Into Conformiq

4.9.1 Introduction

This chapter discusses the use or import of definitions specified in TTCN-3 (Testing and Test Control Notation version 3) source code in the Conformiq Modeling Language (QML), i.e., for the specification of QML models. TTCN-3 files compliant to the **European Telecommunications Standards Institute (ETSI) standard ES 201 873-1 (4.2.1)** can be

included as part of Conformiq projects.

Note that the "Equivalent QML" lines shown in the examples of this document do not explain internal handling which is not visible to the Conformiq user but only serve for illustration purposes. The "Example QML use" lines however can be used by the user under the assumption that the Conformiq project includes a TTCN file which includes the TTCN-3 definition stated in the example.

4.9.2 How to Include TTCN Files in a Conformiq Project

TTCN-3 files can be simply added to a project directly as with any other supported file format. Conformiq recognizes a file type based on the file extension. TTCN-3 files must use the extension '.ttcn'.

A Conformiq model is specified using QML and language which includes Java like '.cqa' files and UML statecharts (created using Conformiq Modeler) in '.xmi' files. TTCN-3 files provide type and constant definitions that can be referenced from code '.cqa' files or diagrams in '.xmi' files. In spite of the fact that only constant and type definitions are imported by Conformiq, TTCN files may contain any syntactically valid TTCN-3 definitions. The Conformiq engine ignores the other TTCN-3 definitions such as templates, functions, altsteps, test cases, timers etc.

All constants and type definitions from TTCN-3 files are accessible and may be referenced in .cqa and .xmi files at a global scope (without dot notations) regardless of the module and the hierarchical group structure. When referencing imported definitions from TTCN-3 files identifiers (including field names of structured types) have to be postfixed with '_' in the case of a conflict with QML keywords (see Keywords section for the list of CQA keywords). Enumerated field identifiers are prefixed by enumerated type name and then are postfixed by '_' if needed, see below.

For example:

```
const integer this := 1 // conflict with QML keyword this
/*
QML equivalent: integer this_ = 1; // this->this_
Example QML use: int c = this_; // this->this_
*/
```

```
const integer that := 2
/*
QML equivalent: integer that = 2;
Example QML use: int c = that;
*/
```

```
type record R { integer i, float f }
/*
QML equivalent: record R { integer i, float_ f }
Example QML use: R r; r.i = c;
*/
```

All TTCN imported TTCN identifiers are global regardless of the module and the hierarchical group structure. Name conflicts at a global scope must be avoided.

For example:

```
const integer i := 1;
group g
{
    const integer i := 1 // Conformiq reports error: i already defined!
}
```

The following sections explain the details of importing particular definitions from TTCN-3.

4.9.3 Basic types

All TTCN-3 basic types except the TTCN-3 `verdicttype` and `universal`

`charstring` types are imported by Conformiq. In the current version, any subtyping restrictions are ignored. Therefore the following pieces of code are equivalent from a Conformiq point of view:

```
type bitstring BitStrings1 ('0'B, '1'B );
type bitstring BitStrings1;
```

The table below summarizes the TTCN-3 basic types support by Conformiq.

TTCN-3 type	*QML identifier*	*QML equivalent*	*Notes*
`integer`	`integer`	`int`	`integer` is directly mapped to QML `int` type (unlimited precision)
`float`	`float_`	`float`	`float_` is directly mapped to QML `float` type (unlimited precision)
`boolean`	`boolean_`	`boolean`	`boolean_` is directly mapped to QML `boolean` type
`bitstring`	`bitstring`	`String`	`bitstring` is directly mapped to QML `String` type. In the current version of Conformiq, `bitstring` may contain sequences of arbitrary characters (not only `1` and `0`). For the compatibility of user code, we strongly recommend to assign strings containing only **ASCII** characters `0` and `1`.
`hexstring`	`hexstring`	`String`	`hexstring` is directly mapped to QML `String` type. In the current version of Conformiq, `hexstring` may contain sequences of arbitrary characters (not only hexadecimals). For the compatibility of user code, we strongly recommend to assign strings containing only hexadecimal characters.

`octetstring`	`octetstring`	`String`	`octetstring` is directly mapped to QML `String` type. In the current version of Conformiq, `octetstring` may contain sequences of arbitrary characters (not only hexadecimals and its length maybe odd). For the compatibility of user code, we strongly recommend to assign strings containing only hexadecimal characters.
`charstring`	`charstring`	`String`	`charstring` is directly mapped to QML `String` type. In the current version of Conformiq, `charstring` may contain sequences of arbitrary characters (not only 7 bit ASCII printable characters). Note also that the escape character is different in TTCN-3 and common escape sequences like `'/r/n'` are interpreted as characters in TTCN-3. For the compatibility of user code, we strongly recommend to use only 7 bit printable ASCII characters in such strings.
`universal charstring`	**Not supported**		
`verdicttype`	**Not supported**		

4.9.4 Record, Set and Union Types

TTCN-3 record and set types are mapped by Conformiq to the QML record type and unions to the QML union type. TTCN-3 records and sets are absolutely equivalent from the point of view of programming in QML. Fields of structured types can be accessed using the dot notation. Nested TTCN-3 field type definitions are also supported. Recursive definitions, although possible in TTCN-3, are not supported by the current version of the TTCN importer.

For example:

```
type record R { enumerated { red, green, blue } color, float f} ;
/*
QML use: R r; r.color = R.color_green; r.f = 3.1415;
*/
type union U { integer i, boolean b} ;
/*
QML equivalent: union U { integer i, boolean_ b }
QML use: U u; u.i = 42; u.b = true;
*/
type union Recursive {
  float dummy,
/*
Conformiq will report an error here
*/
}
```

Note that there is no type compatibility in QML, e.g., values of two different record or set types with identical structure cannot be assigned to each other like in TTCN-3. Record or set fields declared as optional in TTCN-3 are mapped by Conformiq to fields of template type `Optional<T>`.

For example:

```
type record R3 { integer i optional; }
/*
QML equivalent: record R3 { Optional<integer> i }
QML use: R3 r3; r3.i = omit;
*/
```

Note that QML (similar to TTCN-3) offers predefined methods to check for the selected alternative of a union value (`ischosen`) and the presence of an optional record field value (`ispresent`). These predefined methods are referenced without the "_" postfix.

4.9.5 List Types

The TTCN-3 record of and set of collections are mapped to QML array definitions. Any subtyping information such as length restrictions are ignored by Conformiq. Note however, that the QML array length has to be manually specified when creating an instance of an array.

For example:

```
type record length(10) of integer Integer10 // Note that length restriction is
ignored!
/*
QML equivalent: record Integer10[];
QML use: Integer10 i10= new integer[10]; i10[0] = 42;
*/
```

4.9.6 Enumerated Types

Fields of enumerated field values are mapped to global CQA integer constants. Therefore, unlike to TTCN-3 name conflicts may arise from fields of different enumerated definitions.

For example:

```
type enumerated E { one(1), two(2) }
/*
QML equivalent: E E_one = 1; E E_two = 2;
*/
```

Mapped enumerated values may also be assigned to QML variables or fields of integer types. But it is strongly recommended to use the predefined QML method `TTCN_enum2int` for future compatibility. The conversion from the enumerated name into the int value is performed as specified by the TTCN-3 standard.

For example:

```
type enumerated E { one(1), two(2) }
/*
QML use: int dummy = TTCN_enum2int(E_one)
*/
```

4.9.7 Aliasing

TTCN-3 aliasing is supported and mapped to QML aliasing.

For example:

```
type integer Integer
/*
QML equivalent: typedef integer Integer;
*/
```

4.9.8 Constants

Only the importing of TTCN-3 constants of the basic type is supported by the current version.

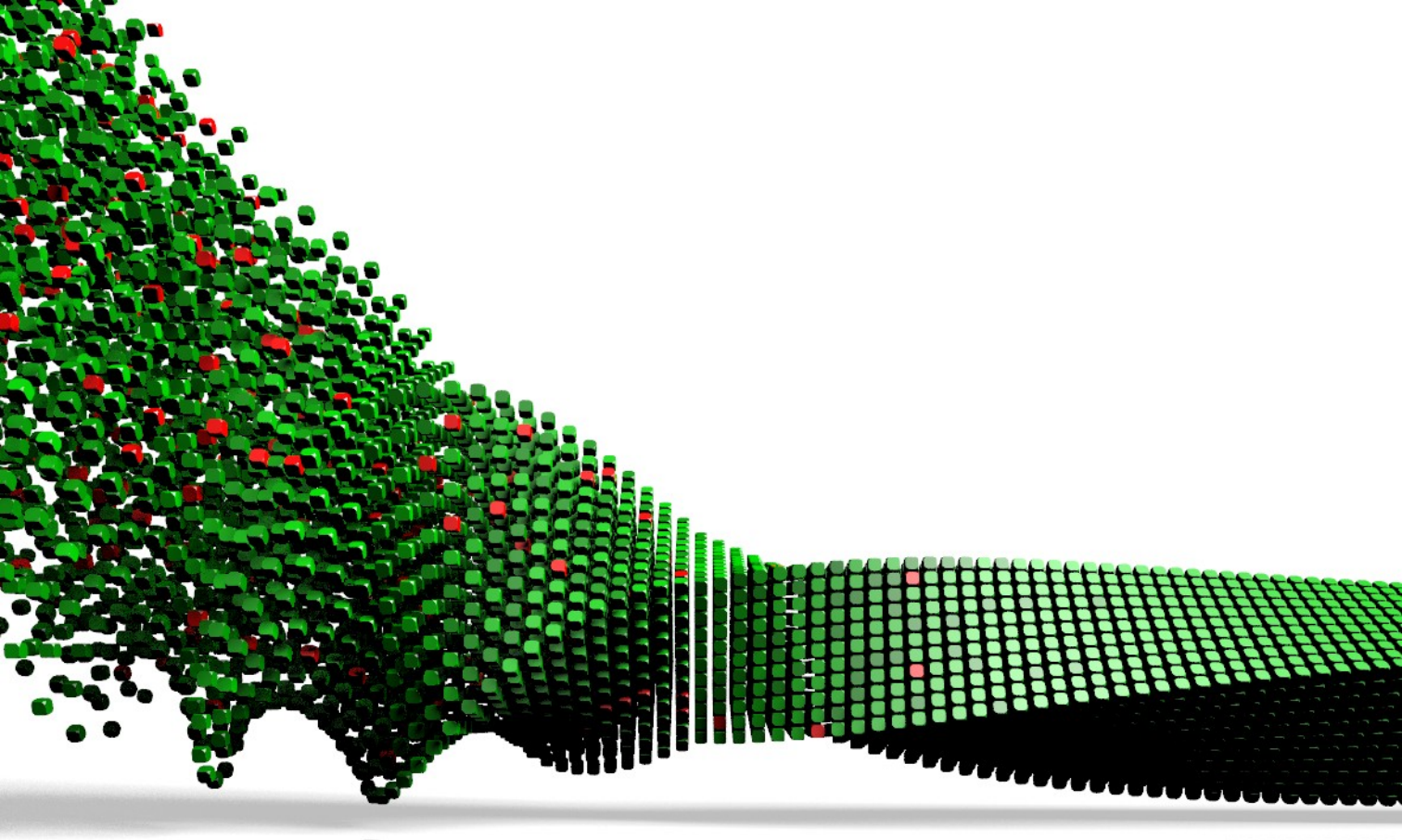
4.9.9 Special types

TTCN-3 special types such as port, component, address and anytype are not supported. Port and component declarations are ignored.

4.9.10 Summary of TTCN-3 limitations

- no namespaces
- no subtyping
- no templates, functions etc.

- no checking of string values
- no type compatibility
- enumerated fields are visible at global scope; name conflicts are possible
- no mapping for verdict type and special types
- no recursive type definitions



5 Using Conformiq Modeler

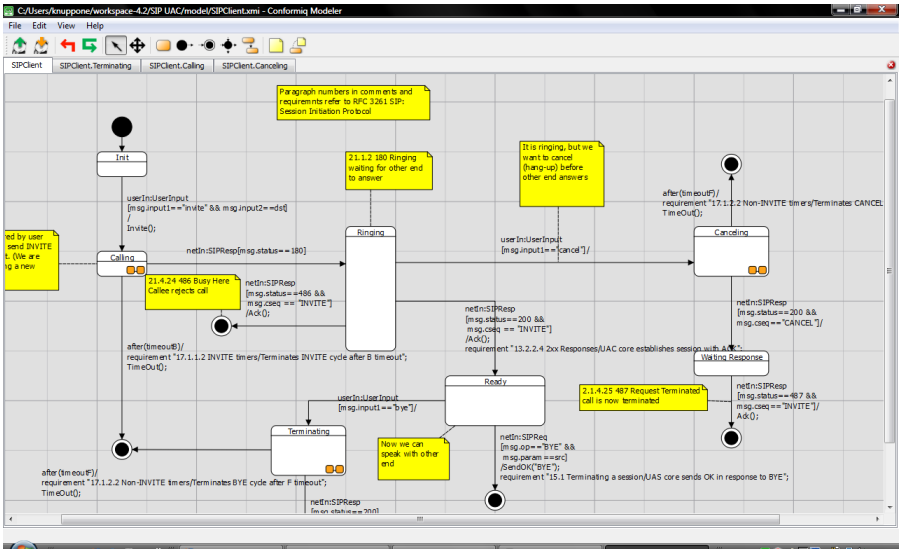
Conformiq Modeler is a simple tool for drawing UML statemachine diagrams. It is used for the graphical notation of QML.

With **Conformiq Modeler** you can have any number of statemachines in a model. For each statemachine there is a diagram which represents the statemachine in graphical notation. Even though a statemachine and a diagram are not the same thing, in the case of **Conformiq Modeler** there is no need to make a distinction between a statemachine and the diagram representing the statemachine.

The **Conformiq Modeler** main window possibly contains an open diagram, a Model Element Tree, a toolbar, and menus. If no model is open, or a model is open but all diagrams are closed or do not exist, then the tool proposes creating a new model or a new statemachine.

The toolbar contains the actions most often needed from the menus. The highlighted tool indicates which drawing action is in use.

Diagrams are shown in tabs where the tab name is either the name of the statemachine, or in case of a sub-state diagram, the name of the parent state.


C:/Users/knuppone/workspace-4.2/SIP UAC/model/SIPClient.xmi - Conformiq Modeler
File Edit View Help
SIPClient
SIPClient.Terminating
SIPClient.Calling
SIPClient.Canceling
Paragraph numbers in comments and requirements refer to RFC 3261 SIP: Session Initiation Protocol
Init
21.1.2 180 Ringing waiting for other end to answer
It is ringing, but we want to cancel (hang-up) before other end answers
Calling
Ringing
Canceling
Terminating
Ready
Waiting Response
21.4.24 486 Busy Here Callee rejects call
2.1.4.25 487 Request Terminated call is now terminated
Now we can speak with other end
An Example Model in Conformiq Modeler

The dockable Model Element Tree is by default at the bottom of the window. The Model Element Tree is a tree view for all statemachine elements of the model. The names of the statemachines or states can also be modified from the Model Element Tree by clicking the corresponding element. Also, a diagram for the statemachine is opened or made active in the tab view if you double-click the statemachine or a basic state with sub-states. Most notably, the Model Element Tree does not contain notes, which are only additional textual comments for the state machine, but only semantic elements of the model.

5.1 Opening a model

You can open a model by selecting Open from the File menu. You can also open any of the ten most recently opened models from the Open Recent menu under the File menu.

The native file format of Conformiq Modeler is XMI (which is an Object Management Group standard for exchanging metadata information via XML) and the file extension it uses is **.xmi**. However Conformiq Modeler can only operate with files created using it and cannot import files from 3rd party tools; this also means that XMI files created using 3rd party tools cannot be opened with Conformiq Modeler.

5.2 Saving a model

A model can be saved at any time by selecting Save from the File menu. Also if you want to save the model with a different filename, choose Save As... from the File menu. A dialog is shown where you can select a new filename for the model to save as.

5.3 State machines

A model can contain a variable number of statemachines. When you have neither a statemachine nor a sub-state diagram open, you will see a "New state machine" button which can be used to create a new statemachine for the model. You can also create new statemachines from the Edit menu at any time.

Diagrams can be closed from the upper right corner of the diagram where the red button with a cross × is shown. You can open closed diagrams by double-clicking an element in the Model Element Tree.

5.4 Drawing

When you have a statemachine created and a diagram open in the main window, you can choose a drawing tool from the toolbar. Click the tool you want to use, e.g., basic state to create a new basic state. Then just press the left mouse button down somewhere in the diagram, and move the mouse while pressing the button so that you can select a region (size) for the state. Release the button when you are finished. To draw a transition, choose the transition tool from the toolbox, and click inside a source state first, then inside a destination

state. A new transition appears by default with its route auto-layouted, i.e., **Conformiq Modeler** places the transition in a straightforward way for you. You can edit the transition text by double-clicking over the transition text. By default, a new transition text contains no signal, an empty guard, and no action. (This means that the transition text is initially "[]/".)

For each element type, some extra actions can be made. Such actions are found in the top menu, and also in the context menu. The context menu appears by clicking the right mouse button in the diagram area. If multiple elements are selected, then the context menu covers actions which are meaningful for the whole selection.

5.4.1 Zooming

If the diagram does not fit in the window, you can freely zoom in and out with the mouse wheel, and from the View menu. The zoom can be reset to 1:1 from the View menu.

5.4.2 Scrolling

You can select the Hand tool from the toolbar and freely scroll the viewable area by dragging it. The arrow keys are shortcuts for scrolling. Scrollbars will also appear if some elements are outside the viewable area of the diagram.

5.4.3 States

Conformiq Modeler supports initial states, basic states, junctions and final states. A basic state can contain sub-states. Sub-states can be drawn for a basic state by choosing "Expand" from the context menu of the basic state. If a basic state has at least one sub-state, an icon resembling two small states with a transition between them is shown in the lower right hand corner of the basic state. A basic state can also contain a set of internal transitions. A name of a basic state can be edited by double-clicking the state name. Internal transitions can be edited by double-clicking below the header line which separates the name and the body of the state.

Junction states are similar to basic states, but they have no name, and they cannot contain

sub-states.

Each diagram may contain only one initial state; a diagram having two or more initial states is erroneous. An initial state is similar to a junction with an additional meaning that the execution of the state machine or the sub-state starts from the initial state. A final state is also similar to a junction with an additional meaning that the execution ends there. Also, a final state cannot be a source point for a transition, and an initial state cannot be a destination point for a transition.

5.4.4 Transitions

A transition is shown as an arrow between a source state and a destination state and it can have multiple route points. When you draw a transition, auto-layout places it by default. However, if you enter more than one middle point while drawing the transition, auto-layout is disabled for the transition.

When a transition has auto-layout in use, then moving the state, or adding more transitions to the source or the destination state, will intelligently modify the route where the transition is drawn. Auto-layout can be switched on or off from the context menu of the transition. When auto-layout is off, you can also add and remove middle points from the context menu, and move the transition text freely.

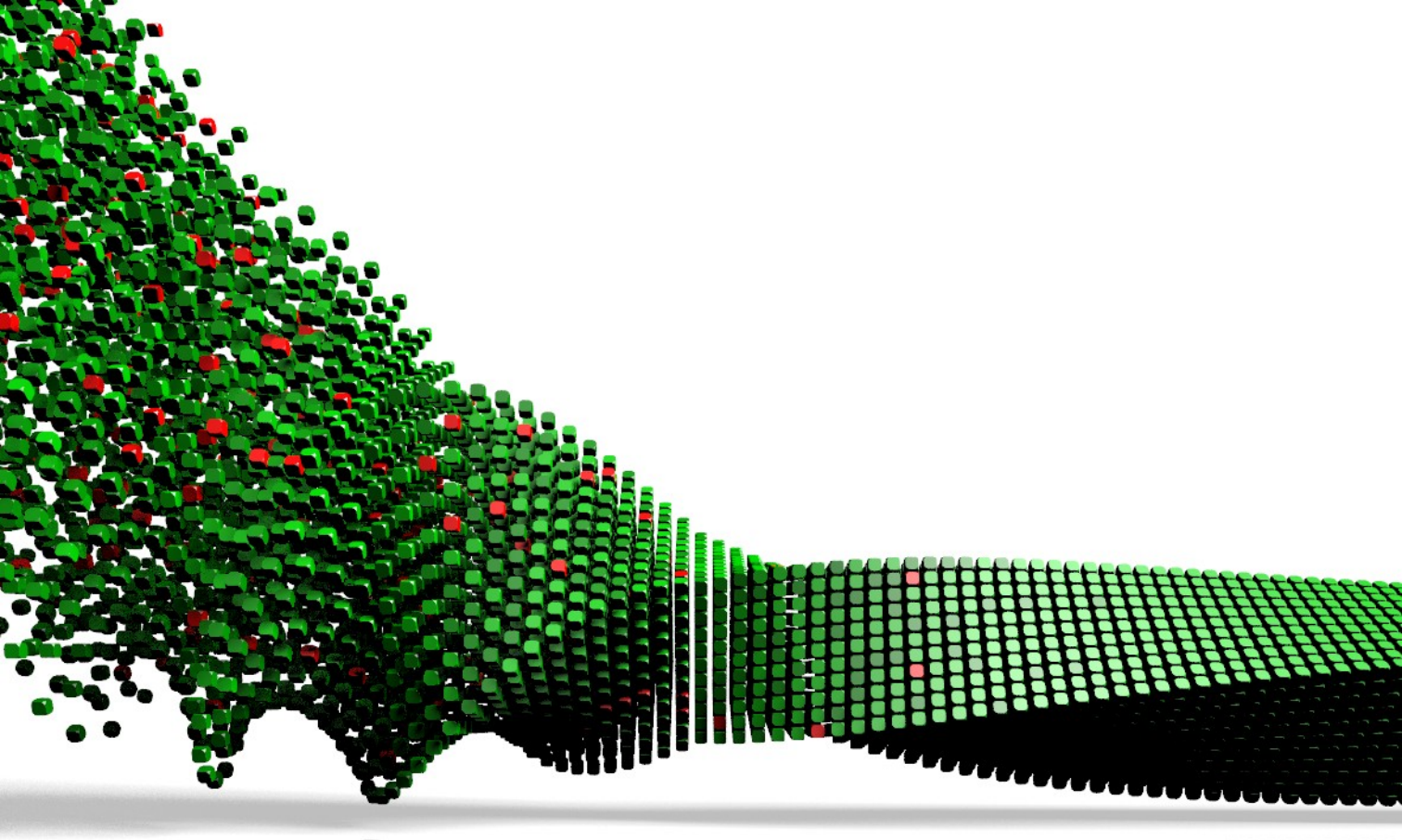
Each transition contains a text block, where a trigger, a guard, and/or an action can be entered. See Transition Strings for more information about the syntax of the text blocks.

5.4.5 Notes and note connectors

Notes and note connectors are elements used only for commenting; **Conformiq Designer** does not give any semantic meaning for them during testing. A note is a yellow box where you can write arbitrary text. A note connector is simply a line which points from a note to the element which the note concerns.

5.5 Undo and Redo

Conformiq Modeler has a global undo feature. You can undo any change in the model regardless of the diagram currently visible. You can also redo changes. You will find Undo and Redo in the Edit menu and also in the toolbar.



6 Importing Models from Third Party Tools

As mentioned in Chapters Using Conformiq Modeler and Creating Models in QML, Conformiq Modeler can be used to create the graphical parts of a design model. Once the textual and graphical parts of the model have been created, all the files that must be compiled and imported into Conformiq are placed under the model directory of your Conformiq project.

However Conformiq Modeler is not the only tool that can be used to create the graphical parts of the model. Instead Conformiq can also import UML state machine and class diagrams from a number of third party tools. As with Conformiq Modeler, the action language used in these models is the textual notation of QML (Conformiq's extended Java/C# language. See Chapter Creating Models in QML for more details).

This Chapter covers the details on how to export a model from a given third party tool and how to import it into Conformiq.

6.1 Enterprise Architect

Sparx Systems (www.sparxsystems.com) Enterprise Architect is a software modeling and construction tool based on the UML 2.1 standard. Enterprise Architect incorporates the full life-cycle of system development. Conformiq supports importing UML state machines and class diagrams. However, Enterprise Architect can be used to make models of other UML types which do not have a good translation to Conformiq state machines and QML action language.

Before importing an Enterprise Architect model into Conformiq, the model must be exported as XMI. The convention is to name the exported XMI model using the `.xmi` file extension. Conformiq supports importing UML 2.0 or UML 2.1 models in XMI 2.1 format.

The action language used in models is always the textual notation of QML and this is also true for Enterprise Architect. Therefore the text on transition strings

must be QML.

Currently models created using Enterprise Architect versions 7.5.X and 8.0 are supported.

6.1.1 Imported Components

The subset of supported state machine diagram elements is the same as that which **Conformiq Modeler** supports, i.e.:

- Classes
- State machines
- Sub state machines
- Initial states
- Final states
- Junction states
- Choice points
- Transitions

6.1.2 Project Layout

An Enterprise Architect project consists of packages. In order to get a good mapping between Conformiq elements and elements defined in Enterprise Architect, the names should not contain spaces. Each package or class can contain at most one state machine. If a package contains a state machine, the name of the containing package is interpreted as the name of the state machine.

6.1.3 Declaring State Machines

In Conformiq QML, state machines are classes which extend the StateMachine class. The `run` method of these state machines can be defined with a special graphical notation. A state machine can be defined in Enterprise Architect in two ways:

- A class contains the statemachine as a behavior.
- A package contains a statemachine as an element and the name of the package is used to name the containing state machine.

If a package or a class contains a statemachine as an element, there can be only one statemachine in that package or class (but there can be many sub state machines). Thus the name of the state machine in the Enterprise Architect element is ignored.

6.1.4 Defining Transitions

Transitions are imported into Conformiq with the body written in the Conformiq action language.

Trigger

In Enterprise Architect, transition triggers have a type which can be either Call, Change, Signal or Time. Conformiq Modeler supports importing the types *Signal* and *Time*.

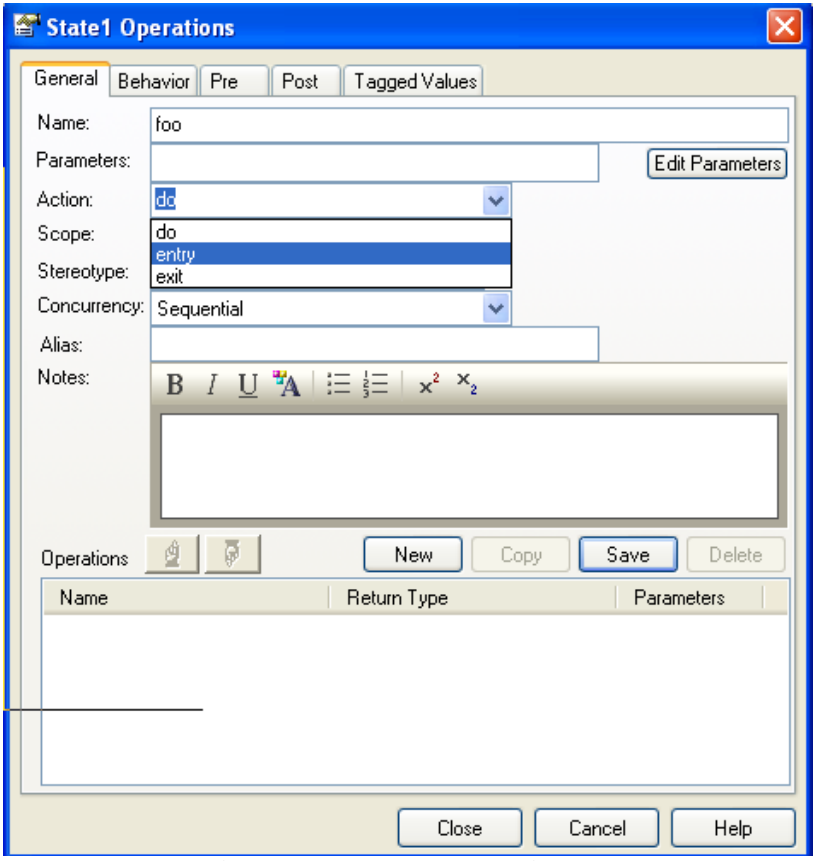
The name of the *Signal* trigger is parsed by the Conformiq compiler as a trigger string. This must have the form '<port>:<type>' similarly to models made with Conformiq Modeler. The first part defines the name of the port from which you expect a message to arrive and the second part defines the type of the message that you expect. The port name in a trigger must be defined inside the system block as an input port, or it may be a case where the internal port associated with the state machine holding the transition is used.

Time triggers take a timeout numeric value. The behavior of the timer event is such that if none of the other triggers fire in the current state within the specified timeout interval, the time trigger will. A timer is initialized only when a state with a leaving transition having an

after is entered. If such a state contains a hierarchy, none of the firings of the transitions that take place within the hierarchy will reset the timer.

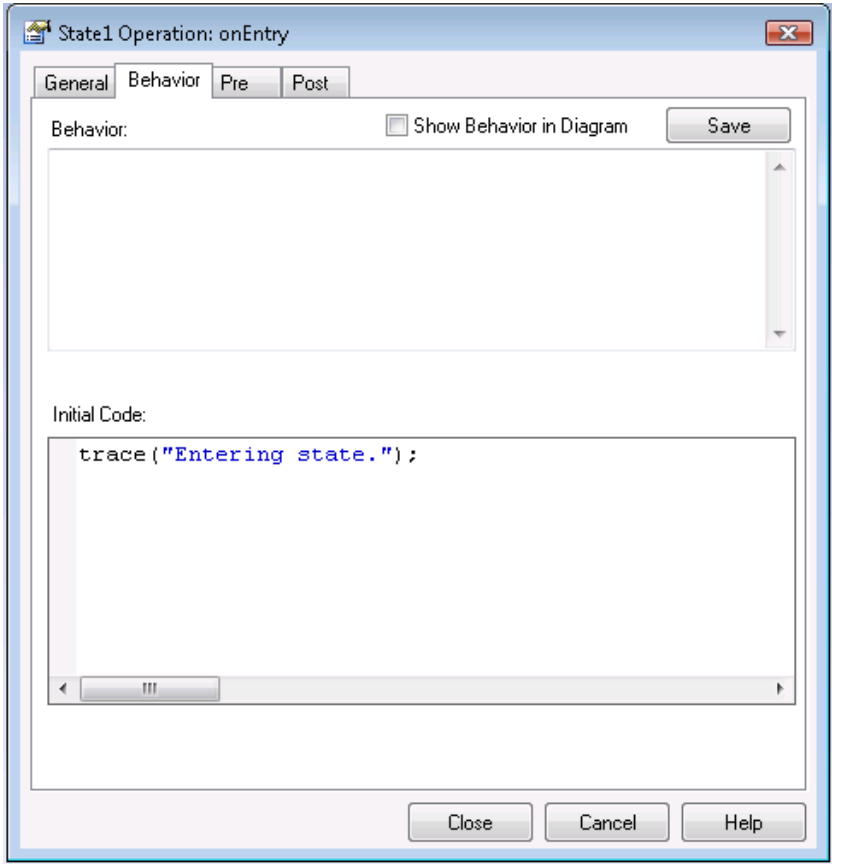
6.1.5 States

States can have entry and exit actions. Defining an entry or exit action for a state is done from the menu "Element > Operations...".



Defining an entry- or exit action for a state.

The body of the operation is given in the block "Initial Code" of the "Behavior" tab of the operation.



The body of an entry action.

Note that the name of the operation, either entry- or exit- action, is in fact irrelevant. Conformiq is only parsing the body of the operation.

6.1.6 QML Tagged Comments

The Conformiq model compiler treats all notes the content of which begin with '`// QML`' as Conformiq action language code. The body text is passed on to the parser and typechecker as written. The location of the note in the model is irrelevant. It would be equivalent to write the comment body inside a file and pass this file to Conformiq Designer.

6.1.7 System Block

Every Conformiq model must define a system block which describes how we can communicate with this model. The class named "System", note the capital initial letter, has a special meaning while importing the model to Conformiq; it will not be translated as a standard class but as the system boundary including interfaces (ports) with the external interface and the main entry point which defines where the execution of the model begins. In order to describe the interfaces in the system boundary, you can drag and drop *Port* to the boundary of the System class; The ports on the boundary of the System class define the interaction between modeled system and its environment and the ports are visible to all the modeled components (i.e. if you declare a port called *external* in the boundary of System class, each modeled component see *external* and can operate with it). Ports are always bidirectional, so they can be used for receiving messages from the external environment and sending messages to it.

Port is available in the *Composite Diagrams* so in order to drag and drop a Port to the boundary of System class, one must select *Composite* from *Toolbox* of Enterprise Architect.

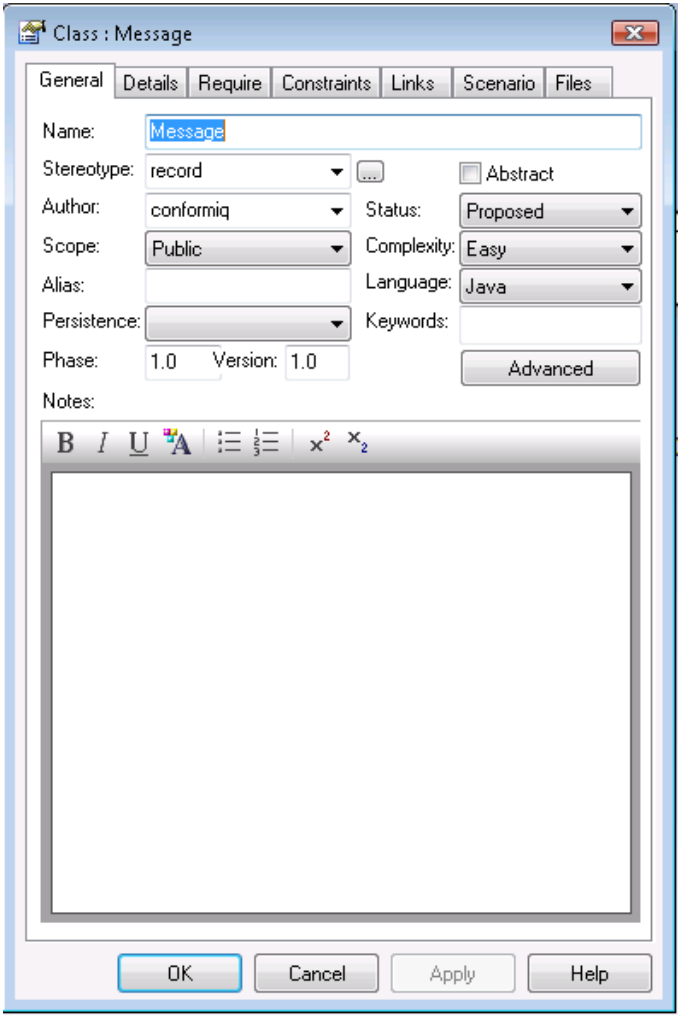
If the model contains System class without any ports on its external boundary, the Enterprise Architect model importer expects that the *system block* is defined elsewhere.

6.1.8 Main Entry Point

All Conformiq models must have a main entry point. If it is given inside the Enterprise Architect model, it can be defined in a QML Tagged comment. It can also be provided in its own file or as a method of a class named "System". In the last option the function name must be "main", have type "void" and have no arguments as if written in QML notation.

6.1.9 Records

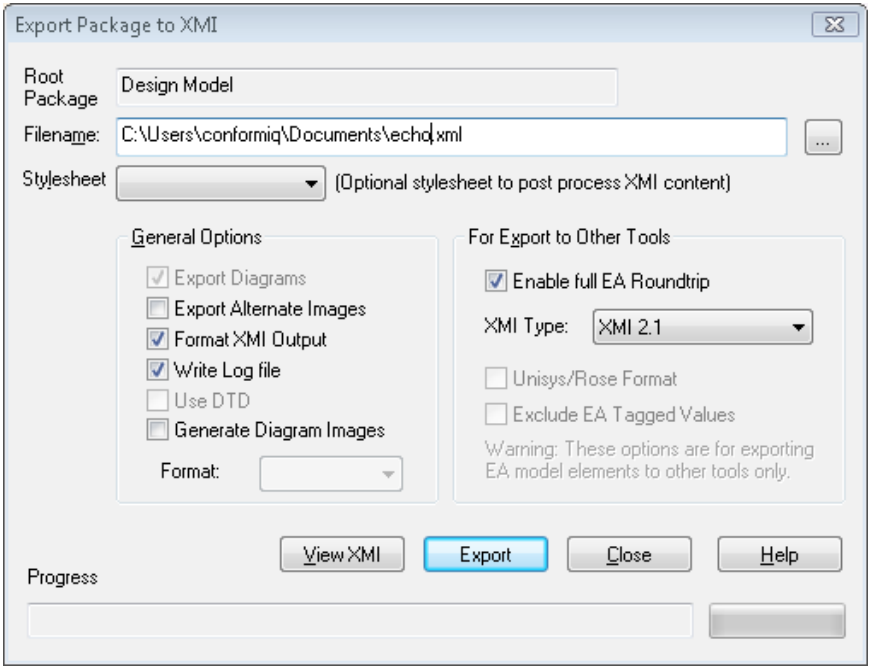
Conformiq QML records can be defined in EA by giving a class stereotype "record" or "qmlrecord". In the names of these stereotypes the case is not relevant. Thus, also "Record" and "QMLRecord" are accepted. Naturally, record types can also be defined in the textual model part.



A class stereotyped as a QML record.

6.1.10 Exporting from Enterprise Architect

Once the model has been created, it must be exported as XMI and imported into Conformiq. In order to export the model as XMI, right click the created root package in the *Project Browser* and select from the menu "Project > Import/Export > Export Package to XMI....". From the opened window, specify the filename into which the model is stored in XMI format. The dialog also gives other options. XMI type must be either "UML 2.0 (XMI 2.1)" or "UML 2.1 (XMI 2.1)". We recommend to choose the "Enable full EA roundtrip" option and type "XMI 2.1".



Exporting Enterprise Architect model as XMI

6.1.11 Importing into Conformiq

Once the model has been created and exported from Enterprise Architect, all of the files

associated with the model must be imported into Conformiq.

When the model file is successfully imported into the Conformiq Eclipse Client you can load the model into the Conformiq Computation Server for compilation.

When the model has been successfully compiled you can proceed with test generation. Test generation and management are done in the same way as with any other model.

6.1.12 Components not Imported

Note that while using Enterprise Architect one can add elements which, even though they are UML compliant, either do not have any translation into Java, or which are internal references of Enterprise Architect.

6.2 Rhapsody System Designer

Rhapsody System Designer by IBM/Telelogic (http://www.ibm.com/) is a model driven development tool. Here we show how this tool can be used with Conformiq to model the behavior of the system under test.

6.2.1 Imported Components

- The subset of supported state machine diagram elements is in most parts the same as that which Conformiq Modeler supports:
  - State machines
  - Sub state machines
  - Initial states
  - Final states
  - Choice and junction points
  - Transitions

- As of Conformiq Designer 4.4.1 the composite states and orthogonal regions are supported by the model importer.
- Timer triggers are modeled using Rhapsody's timeout mechanism, i.e., the `tm()` function. Note that `tm()` uses milliseconds as the input parameter.
- Rhapsody choice point semantics is maintained through the model import and is different from the semantics of a junction state in Conformiq Modeler. The Rhapsody choice point (or condition connector) represents a *static* choice, i.e., the guards on the outgoing transitions are evaluated before the transition is taken.
- The action language used in models created with third party tools is always the textual notation of QML and this is also true for Rhapsody models. Therefore the text in transition strings must be QML.
- When creating Rhapsody models, Rhapsody's internal file format (.sbs file) is used by the Conformiq model importer. The .sbs file to be imported by Conformiq Designer can be found under the Rhapsody project directory (<project-name>_rpy) located in the appropriate package (<package-name>_Pkg) directory. It is good practice to save the Rhapsody project in your Conformiq Designer project directory next to your model directory. This makes it easy to link the .sbs file into the Conformiq Designer model directory.
- Ports can be added to the "system" class, and they are ignored elsewhere. A Port defines its direction by either "providing" interfaces or "requiring" them. A port that specifies provided interfaces will be considered as an inbound port by Conformiq. In contrast a port requiring interfaces will be considered to be outbound. A port is not allowed to both provide and require interfaces.
- There is a special predicate for ports to be used in transition predicates, `boolean isPort(CQPort)`. This function returns true for the port through which a message has been received. It can only be used inside a guard, it must be the first element in the expression and cannot be negated. For example guards `[isPort(a) && isPort(b)]` or `[!isPort(a)]` are not valid.

- Sending messages through a port is done in the QML way. For example, sending a message 'msg' though a port 'out' is done with the below syntax, which differs slightly from the standard Java-port semantics present in Rhapsody.

```
out.send(msg);
```

- If the system-class does not specify any ports the importer defines an inbound port *input* and an outbound port *output*.

Adding the Main Entry Point

The main entry point to the model is defined as a member function (or operation) "main" implemented in a "System" class. I.e. the main entry point to the model is created as follows

- add a class called "System" into the Rhapsody model
- add a member function "main" to the newly created "System" class

The "main" function may not take any arguments and it does not return a value.

Defining Records

The communication between the model and the SUT is done using QML records. Records correspond to Rhapsody events. If there is a need for complex record definitions then these should be defined as classes stereotyped to "records". It is then easy to choose these stereotyped classes when defining events.

6.2.2 Example Echo Model

Let us first examine a very simple model in QML, the Echo model. This is a model of a system which responds to every message sent to it by sending the same message back. QML ports have a direction and thus the system would have two ports, one for incoming messages and another for outgoing messages. This is what our definition file would look like:

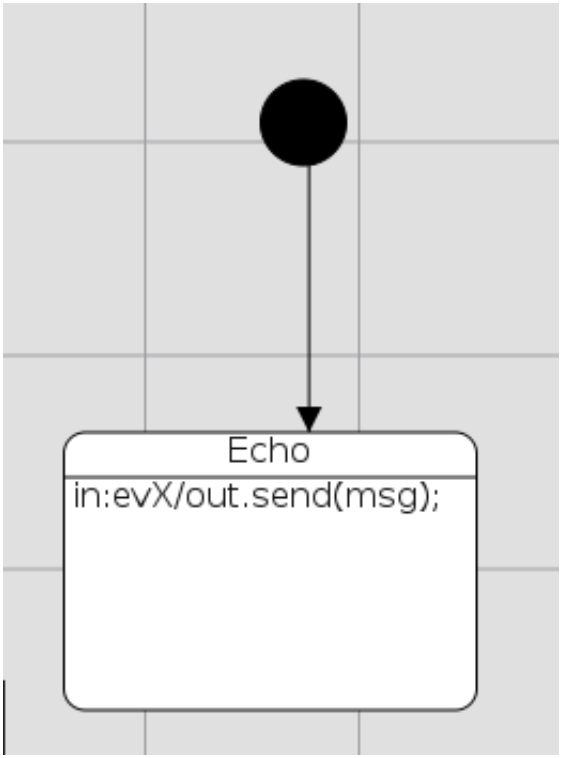
```
system
{
    Inbound in : evX;
    Outbound out : evX;
}

record evX {String str; }

class Echo extends StateMachine { }

void main()
{
    new Echo().start("Echo");
}
```

Here we have specified that the system under test has the two ports for outside communication and through these ports we can pass messages of type 'evX' which contain a single string. There is also the state machine definition for the Echo which is depicted in the figure below.



Echo state machine

The single state inside this state machine "EchoState" has the internal transition:

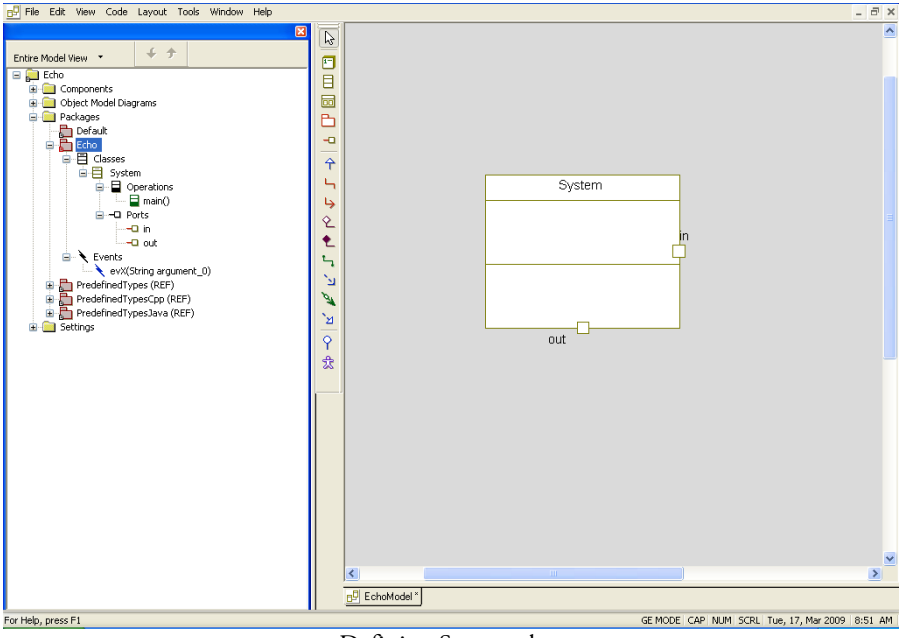
```
in:evX / out.send(msg);
```

which says that when we receive a message from the port 'in' we send it back through the 'out' port. In QML the syntax of the state internal transition is `trigger [guard] / action`, where *trigger* specifies both the type of the message and from which port it came, *guard* is the guard predicate and *action* specifies the action taken.

6.2.3 Example Echo Model in Rhapsody

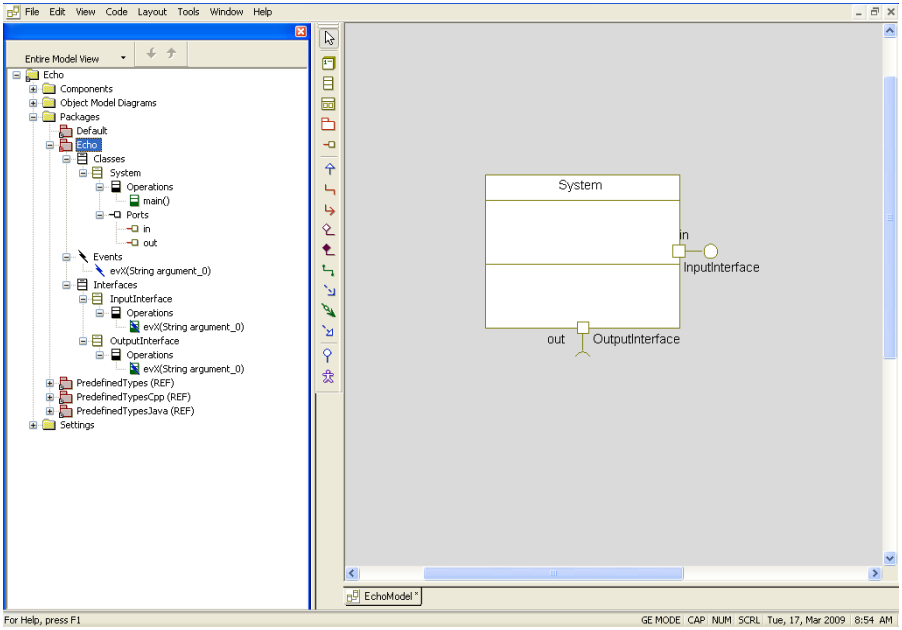
The record 'evX' here corresponds to a Rhapsody 'event', or alternatively to a record stereotyped class as stated above. In Conformiq records are sent and received through some ports and Conformiq ports have a direction. The direction of the port is relayed through the interfaces. The interface 'InputInterface' is a container for the inputs, while the 'OutputInterface' contains the outputs. The events in these interfaces should be set as Receptions to be correctly interpreted by Conformiq.

In Rhapsody we create a class "System" on the top-level of the class hierarchy. Also the `main()` function is under this System class.



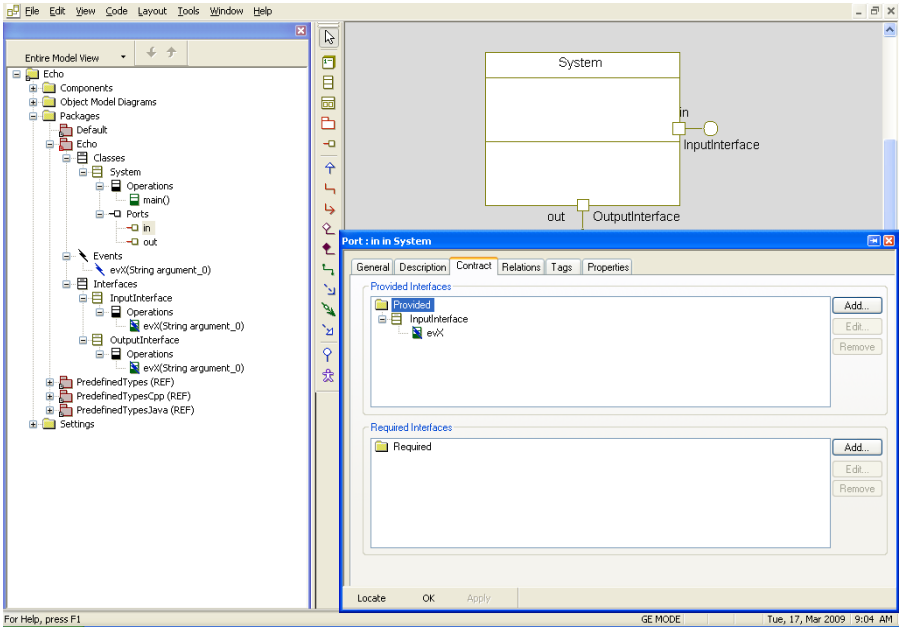
Defining System class

The system ports are added to this class. As mentioned above, since ports in Conformiq are directed, we also require this for the ports defined in Rhapsody. The ports are then added to this System class as shown.



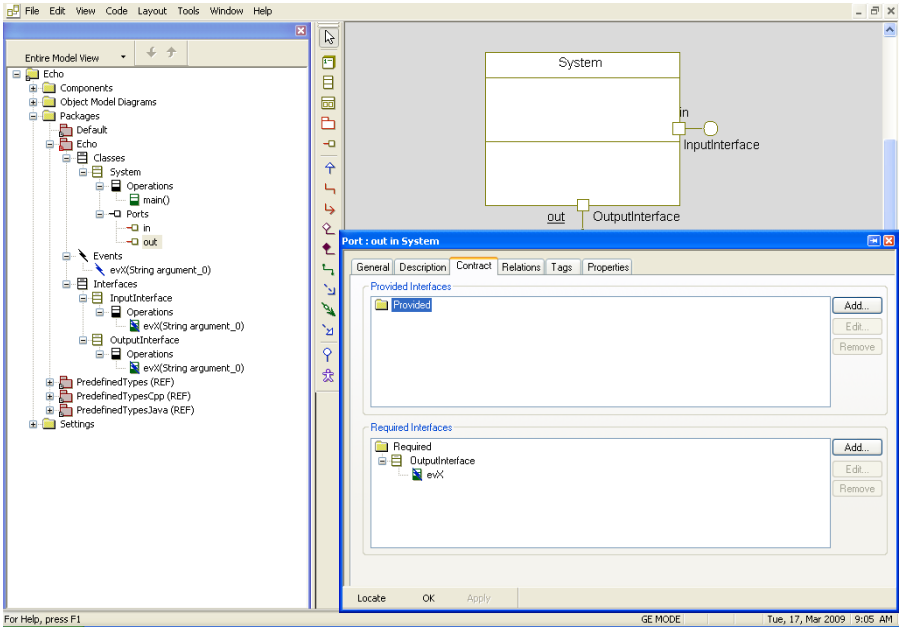
Defining external ports

The 'in' port has a provided interface 'InputInterface' which contains the 'evX' event, and no required interfaces. An interface is interpreted as a set of records which the Conformiq port will accept.



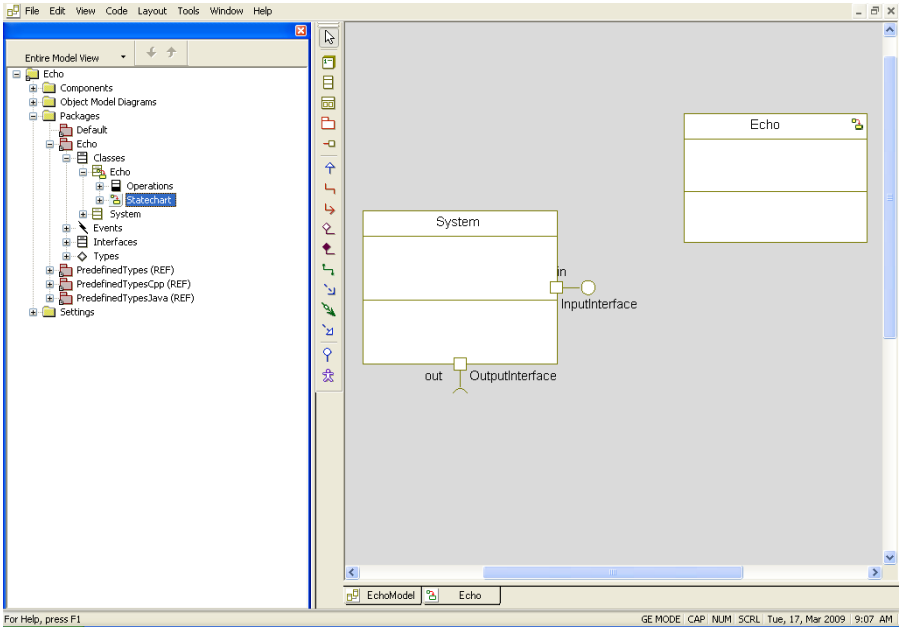
Defining types that can be received from the environment

Likewise the 'out' port has a required interface 'OutputInterface' without any provided interfaces.



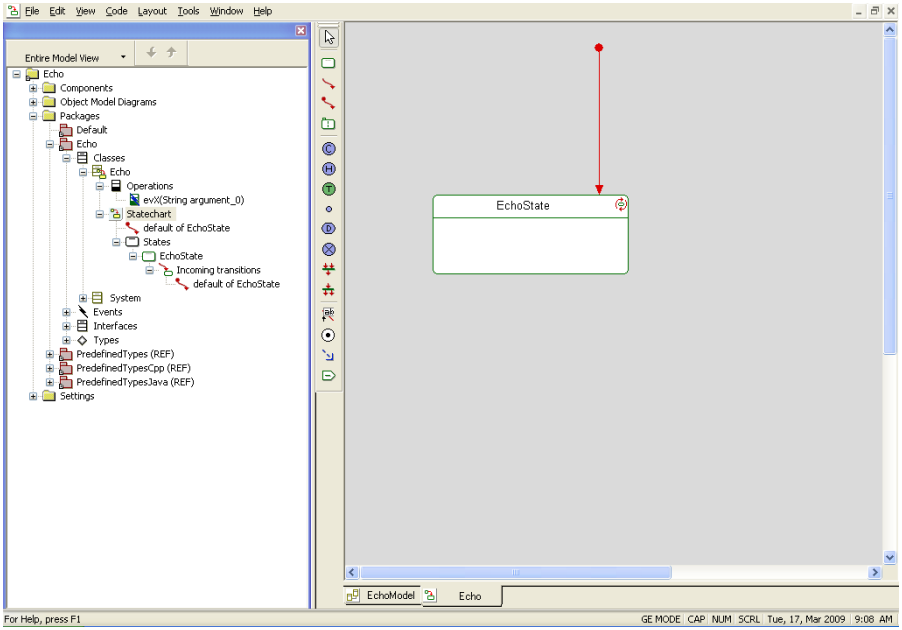
Defining types that can be sent to the environment

After this we create the Echo class with a statechart under the model.



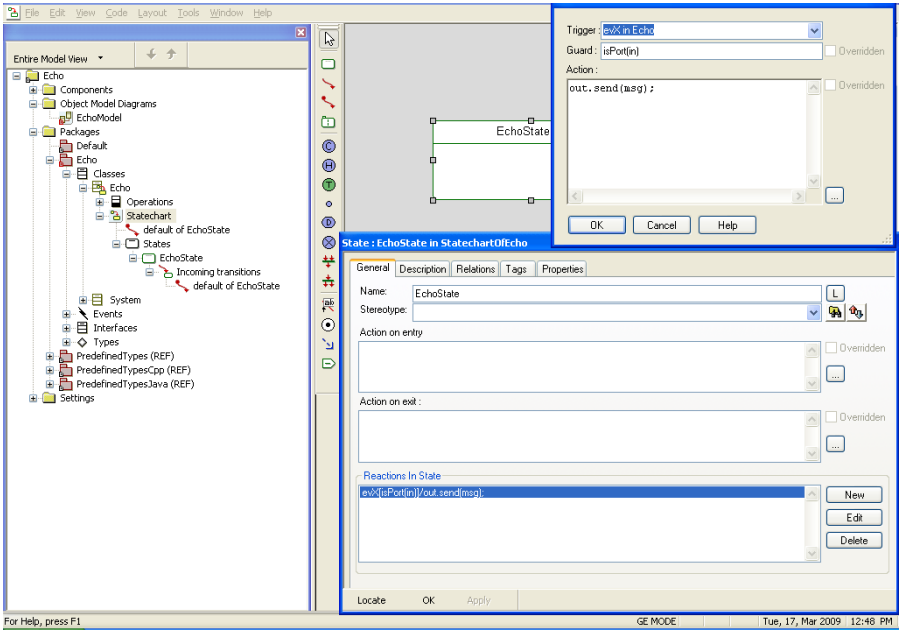
Defining an active class Echo that has a state machine

We then add the Echo class to our model:



Defining Echo class for holding member methods and variables

The Statechart of the Echo class only contains a single state 'EchoState' in addition to the initial state.



Defining the behavior of the echo system using state chart

While the way internal actions are defined in Rhapsody closely matches how state internal actions are handled in QML, there is a difference: we cannot specify the port in the transition trigger as the trigger only allows us to define the type of the event. In Conformiq each such action is associated with one specific port, or 'all input ports' if none is given. However, in Rhapsody the port is checked with the `isPort()` predicate in the guard. Thus the way the above QML transition string is written in Rhapsody is:

```
evX [isPort(in)] / out.send(msg);
```

Best Practices: The Conformiq model import only supports straight or rectilinear transitions. Thus it is advisable to use these, or keep in mind that very curved transitions will look different in the model browser. Also it should be noted that while initial states are very small circles in Rhapsody, they are drawn much larger in the model browser. Thus if an initial state

is close to some other element this may affect the appearance in the model browser.

6.2.4 Summary

We have demonstrated the use of Rhapsody in Conformiq modeling with the help of a simple example. While there is no apparent connection between the System-class and the rest of the model, the System-class is used to represent the model to the outside. The connection with the Echo class is that the main function instantiates this class and starts this state machine. The system block in Conformiq indicates how we can communicate with the system under test from the outside world.

6.3 Rational Software Architect

IBM Rational Software Architect is a powerful integrated design and development solution providing powerful modeling and graphical editing across a variety of domains including UML 2 (for more information about IBM Rational Software Architect, please point your browser to http://www-01.ibm.com/software/awdtools/swarchitect/websphere/)

Supported Versions

Currently models created using IBM Rational Software Architect RealTime Edition (RSARTE) version 7.5.4 or newer are supported.

Supported Modeling Constructs

From models created with IBM RSARTE, Conformiq can import state chart and class diagrams. The following list shows the supported constructs and conventions that must be used in order to import IBM RSARTE models

- The subset of supported state machine diagram elements is basically the same as that which *Conformiq Modeler* supports, i.e.:
  - State machines

  - Sub state machines
  - Initial states
  - Final states
  - Junction states
  - Choice points
  - Transitions
- The action language used in models (when created with third party tools also) is always the textual notation of QML and this is also true for IBM RSARTE. Therefore the text on transition strings, class operations, etc. must be QML.
- Transitions are always signal triggered. Modeling of timeouts is detailed later in this Chapter.
- Before importing an IBM RSARTE model into Conformiq, the model must be exported as XMI. The convention is to name the exported XMI model using the .xmi file extension.

A Simple Worked Example

This Section shows a simple example of how to create a model using IBM Rational Software Architect RealTime Edition. This created model is exported from IBM RSARTE as an XMI file before it is finally imported into Conformiq Designer.

Start by creating a new *Model project*.

- Select **File > New... > Model Project**
- Name the project, f.ex. "First Model Project"
- Add a new *model* to this project by clicking **Next**
- From the opened view, select *Analysis and Design* and *UML Capsule Model*
- Name the created model (f.ex. "Echo") and click **Next**

- Enable all the capabilities from the *Capabilities* window and
- click **Finish**.

The project tree should now looks as follows:

```
First Model Project
  Models
    Echo
      Main
```

Start defining the test interface by right clicking the created model *Echo*.

- From the pop-up menu, select **Add UML > Capsule**
- Name the created Capsule as *System*; this is the test interface. This is a required name which distinguishes this capsule from the other capsules.

RSARTE automatically creates a state machine for each capsule, but as the test interface itself has no behavior, we would like to delete the state machine.

Next add a *protocol* that describes events that are allowed to pass through the test interface:

- Once again right click *Echo* model
- From the pop-up menu, select **Add UML > Protocol**.
- Name this protocol. For example, *SystemBoundary*.

Continue by creating events for the *SystemBoundary* protocol:

- Right click the <<*Protocol*>> *SystemBoundary*
- Create one input event by selecting **Add UML > In Event** from the opened popup menu for new input event
- Name this event as *MsgIn*
- Create one output event by selecting **Add UML > Out Event** from the opened popup menu for new output event

- Name this event as *MsgOut*

Now we need to associate the protocol with the *System* capsule:

- Select the *System Structure Diagram* of the top level *System* capsule and drag the *SystemBoundary* protocol to the boundary of this diagram. This will create a port inside *System* capsule.
- Right click the protocol on the boundary of the *System Structure Diagram*, select **UML RealTime Properties** and unselect **Behavior**. One can do the same using the *Properties* view.

Now that the input and output events are created, we need to define data for these events. This is done by using passive classes, i.e., classes that have no behavior.

- Create a new passive class and name it as *MyMessage*
- Add a new attribute to the passive class
- Name this attribute as *value*
- Right click the created attribute and select *Properties*. This will open the *Properties* view that can be used to change the attribute name, set the type, visibility, etc.
- From the *Properties* of the created attribute, set the type to be *UMLPrimitiveTypes::String* and set the visibility of the created attribute to *public*.

Now select the created *MsgIn* input event in the Project explorer and change the *Data Class* of the event to the *MyMessage* type that was just created.

- Click *MsgIn* event and navigate to the *Properties* view. Select the *General* tab.
- Change the *Data Class* by clicking **Set...** button and then **More...**.
- From the opened window, select **Browse** and then select *MyMessage*.

Change the *Data Class* of the *MsgOut* event similarly.

A new capsule that describes the actual behavior of the system is created as follows:

- Right click *Echo* model in the Project explorer and select **Add UML > Capsule**
- Name this capsule as *Echo*

Now create an instance of this capsule at the top level of the *System* capsule. This is done by opening the *System Structure Diagram* of *System* capsule and dragging the *Echo* capsule into this diagram. This will create a run-time instance of *Echo* in the *System Structure Diagram*.

The next step is to associate the *SystemBoundary* protocol with the *Echo* capsule that is required in order to communicate with the external environment in the *Echo* instance:

- In the *System Structure Diagram* at the top level of the *System* capsule, drag the *SystemBoundary* protocol to the border of the instance of *Echo* capsule
- Draw a connector between the *SystemBoundary* protocol on the boundary at the top level of the *System* capsule and the *SystemBoundary* protocol on the boundary of the instance of *Echo* capsule

Now we need to describe the actual behavior of the *Echo* system in a state machine so the next step is to extend the state machine inside the *Echo* capsule as follows (by default, IBM RSARTE creates a state machine with an initial state and a basic state):

- Create a new state by selecting *State* from the *Palette* and dragging that to the state chart.
- Draw a transition from the basic state already in the state machine to the state created
- Right click the created transition and select **Add Trigger**. This will open a view that shows the ports on the boundary of the given capsule and those events that can be passed via this port.
- Select *systemboundary* from the list of ports on the left hand side of the window and then *MsgIn* as the event that triggers the transition.

Next we need to define a guard condition for the transition which happens via the *Code View* of the guard. Insert the following expression into the *Code View*

```
msg.data.value == "Hello World"
```

Note that this is an expression, therefore do not add semicolon (;) to the end of the guard expression.

Similarly we need to add an action or effect that is executed upon taking the transition. Type in the following code fragment into the *Code View*

```
MsgOut out;
out.data.value = msg.data.value;
systemboundary.send(out);
```

That's it! The model is ready. The next step is to export the model and import it into Conformiq Designer for test generation.

Exporting IBM Rational Software Architect Models

The models created using IBM Rational Software Architect RealTime Edition must be exported as UML2/XMI files before the model can be imported into Conformiq Designer.

IBM RSARTE models are exported as follows:

- Select the model to be exported in the Project explorer by right clicking to it.
- Select **Export** which will open the *Export* wizard
- From the *Export* wizard select **Other > UML 2.1 XMI Interchange Model** and click **Next**
- Make sure that the model that you are exporting is correctly listed in the *Source / Models* text box, and if not, enter the name of the model to be exported there.
- Select the file system directory to which model is to be exported.
- Deselect the *Recreate IDs* checkbox in order to enable the Conformiq Eclipse Client user interface to draw the physical model structure in the *Model Browser*

upon model import. Deselect the *Export applied profiles* as well.

- Finally, click **Finish** which will then export the model in a format that the Conformiq Designer model importer recognizes.

Showing Physical Model Structure in the Conformiq User Interface

In order to see the physical model structure in the *Model Browser* of the Conformiq user interface, the native **EMX** file of the model needs to be placed into the *model* directory of the *Conformiq Project*. This is because the IBM RSARTE XMI exporter exports the logical model structure only without information about the physical locations of entities such as states and transitions. Instead, the physical locations of model constructs are present in the native **EMX** files which Conformiq Designer then reads in addition to the logical model structure.

If you do not wish to see the physical model structure in the *Model Browser*, then the native **EMX** files should not be placed into the *model* directory of *Conformiq Projects*.

How to Define System Capsule

In order to configure your model and describe the external interface, the capsule named *System* must be created. Conformiq Designer distinguishes the capsule *System* from other capsules by name. The *System* capsule usually contains instances of other capsules and ports.

Ports places inside the *System* capsule are recognized by Conformiq Designer as external ports. These ports must be marked as service and non-behavior.

For each instance dragged into the *System Structure Diagram* of the *System* capsule, Conformiq Designer automatically associates a thread and runs a state machine inside it.

How to Define Class Attributes and Operations

You are able to define your own attributes (i.e. member variables) and operations (i.e. member methods) inside capsules and passive classes.

- Select capsule or a passive class which you want to extend with an attribute or

operation.

- From the context menu choose **Add UML > Attribute** for a new attribute and **Add UML > Operation** for new operation.
- Name the newly created element. If you name an operation with the same name as the containing class, it becomes a constructor.
- If you want to create an attribute containing a dynamically growable structure for some elements, set its multiplicity to *1..** (default value is 1) and then write the initialization code inside the constructor. For example if you create an attribute named *container* having *Integer* as the type and multiplicity is set to *1..**, the initializer would be written as follows:

```
container = new Vector<int>();
```

How to Define Internal Ports

In order to create an internal communication port perform the following actions

- Create a new protocol and define input events just as we did in the example above.
- Open *System Structure Diagram* and drag the newly created protocol to the boundary of the sender instance (i.e. an instance of a capsule). This creates a new port inside the sender state chart.
- Similarly, open *System Structure Diagram* and drag the newly created protocol to the boundary of the receiver instance (i.e. an instance of a capsule) which will create a new port inside the receiver state chart.
- Draw a connector between the created ports.
- You are free to name ports on the sender and the receiver sides as you wish. When sending something to an internal port, use `sender_side_port_name.send(someEvent)`. On the receiver side you are

able to handle messages coming from an internal port in the same way as you do with external ports.

How to Define Timeout Triggered Transitions

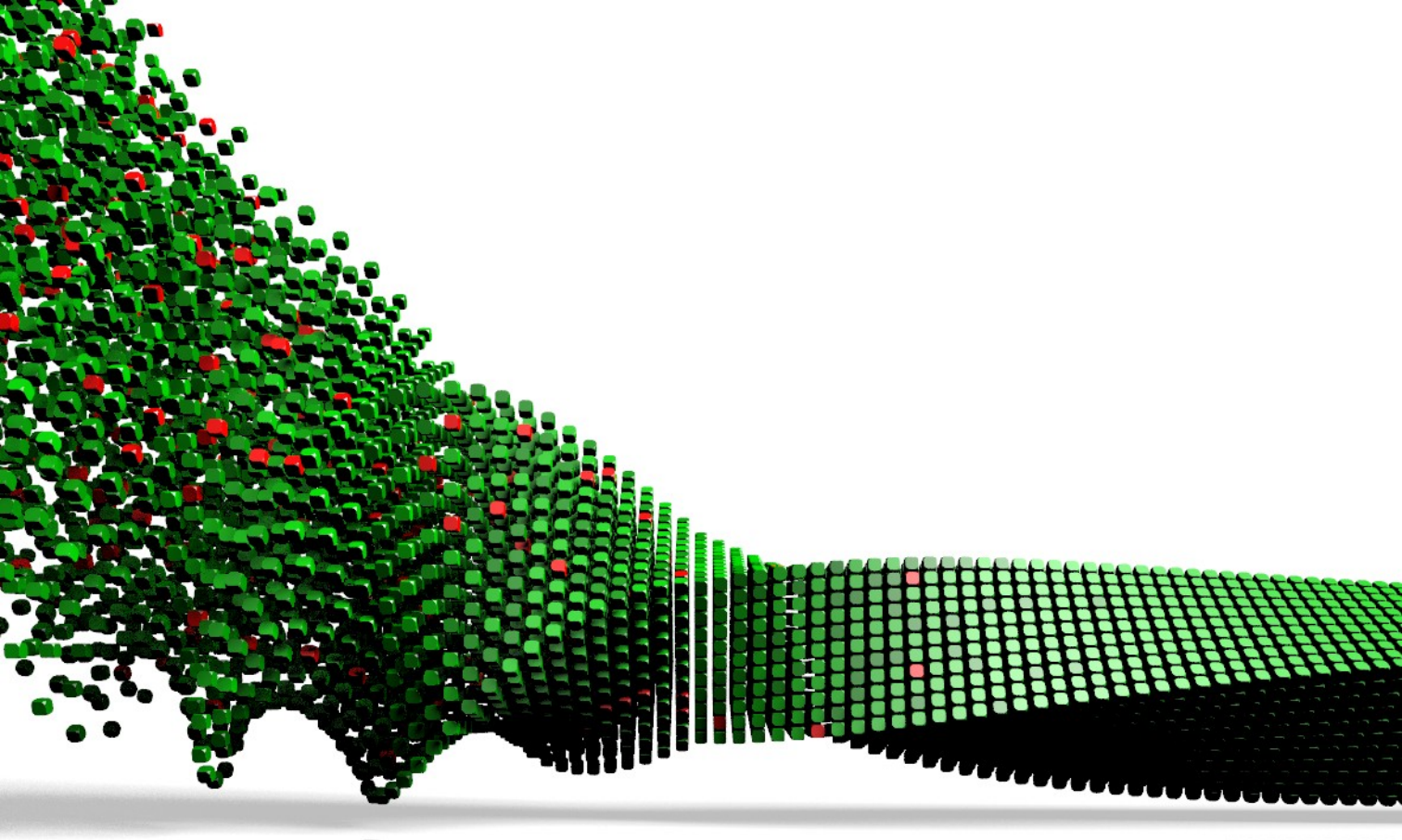
If you want to trigger a transition after a certain period you have to add a port using type *Timing* into the capsule.

- Select a transition that you want to trigger.
- From context menu choose **Add UML > Trigger**. This will open *Add trigger* wizard containing a list of ports that are visible inside the given capsule.
- Click **Add New Port...** which will open *Add Port for Trigger* window.
- Name your timing port for example to *my_timer*.
- At this point, by default IBM RSARTE suggests to create a new protocol. Instead of allowing IBM RSARTE to automatically create this protocol, uncheck the *Create New Protocol* checkbox and click **Browse...**. This will open the *Select Element* window.
- Type "timing" into the *Search* tab and choose *<<Protocol>> Timing – RTClasses::Timing::Timing* and click **OK**.
- Confirm the creation of a new port by clicking **OK** in the *Add Port for Trigger* window.
- From the *Available Events* list in the *Add Trigger* window, choose *timeout* event and press **OK**.

Now you have created a trigger to fire a transition, but the time is not initialized yet. To initialize the timer type, we need to invoke `set()` method of the timer port with a parameter containing the timeout value in seconds. For example:

```
my_timer.set(10);
```

sets the *my_timer* to elapse in 10 seconds. The timer must be set before we can expect to receive a timeout event.



7 Test and Requirement Management Tool Integrations

As of version 4.2.0, Conformiq provides a means for integrating third-party requirement and test management tools.

A Conformiq requirement management tool connector provides a means to check requirement catalogs from third-party requirement management tools against QML requirement statements specified in the model. In order to connect to such a tool, the user needs to select a connector in Conformiq Options and provide connection details in the relevant tool integration submenu. Requirements are then checked during the loading of a model, i.e., after model files have been parsed and checked against errors. If there is a mismatch, i.e., the requirement catalog contains requirements that have not been modeled, a report is produced and presented to the user on the console. Also, if the model contains requirements that are not present in the requirement catalog, the user is also informed. The user can disable the generation of reports for the latter case by ticking the box "Disable notifications about QML requirements missing".

A Conformiq test management tool connector also provides a means to upload generated test cases and requirement coverage information to a specific test management tool. In order to connect to such a tool, the user needs to select a connector in Conformiq Options and provide connection details in the relevant tool integration submenu. The user can then upload generated test cases and requirement coverage information to the test management tool at any time by clicking or selecting "Upload tests". Separation of the actual test generation, rendering, and uploading of test cases to a test management tool makes the work flow intuitive and robust. It allows users to review and validate test generation results in the Conformiq Eclipse Client before uploading them and it allows users to manage the frequency of uploads.

Note that this behavior has changed from Conformiq Designer 4.4.0 where the tests were automatically uploaded to the test management tool immediately after test generation. The problem with that approach was that it lead to the uploading of intermediate tests, i.e., tests that have not been reviewed.

In summary, the following steps should be taken into account when integrating third party requirement and test management tools with Conformiq Designer:

- In each Conformiq project select the applicable requirement and/or test management tool connector(s) within the Conformiq Options of the project properties.
- Configure the selected requirement and/or test management tool integration as documented in following sections
- Click or select “Load model” to automatically check catalogued against modeled requirements via the selected requirements tool
- Click or select “Upload tests” to automatically upload the current test set to the selected test management tool

Third party tool integrations are organized and treated as Eclipse extension components or plug-ins. Users may develop and add further custom tool integrations to other such tools by connecting them via the Eclipse connector interface.

7.1 Configuring a Test / Requirement Management Tool Integration

The testing setups are managed as projects in Conformiq. Each Conformiq project contains a set of model files, test design configurations, and global test generation options. Due to a global nature of requirement management tool integration (i.e. the model files are annotated with a set of requirements) the requirement tool integration is implemented globally on a project level rather than on a test design configuration level.

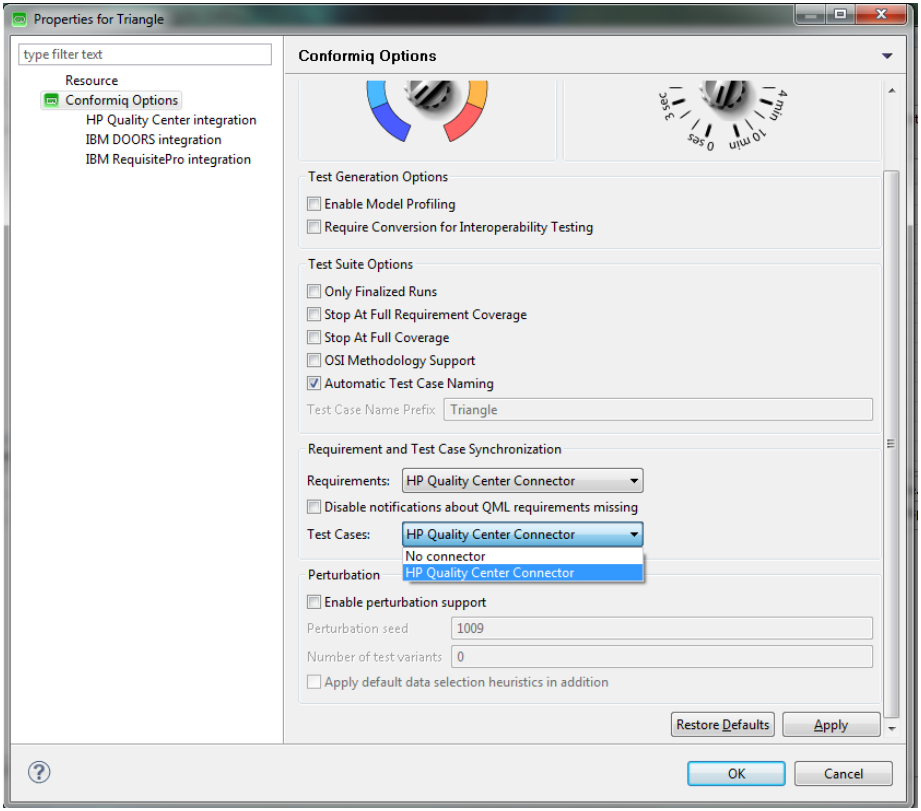
There is a way to configure each project to use a certain requirement management integration. There can be zero to one different requirement management integrations enabled in a single project at any given time. The details of a configuration are always specific to the given integration and that which is defined in a test / requirement management tool plug-in.

As it is not always desirable to have all modeled requirements in the requirement data base,

e.g., "ad-hoc" requirements, you can suppress the warnings about this type of mismatches by selecting *Disable notifications about missing QML requirements*. This option is not set by default.

Similarly to the requirement management tool connectors, the integration towards test management tools is established on the Conformiq project level.

The configuration of the integration plug-ins is done with the Conformiq Project properties, which can be accessed by selecting a given Conformiq project in the Eclipse project explorer, right clicking the project, and selecting Properties from the pop-up menu. Each integration is located under the Conformiq configuration page in the Project properties. The integrations are taken into use and configured this way.



Selecting requirement and test management tool connectors

7.2 HP Quality Center Integration

HP Quality Center is a requirement and test management tool that helps an organization to manage requirements coverage, associated defects, test cases, and allows for managing release process and other quality activities. It is one of the most popular tools used in industry for test execution management. HP QC, amongst other features, enables users within projects to catalog requirements in a folder structure and track their (test) coverage status, getting from a requirement to the corresponding test(s), etc. In addition, informal test descriptions can be

stored in a folder structure, like "Test Plans", and can then be connected to cataloged requirements. Test execution can also be started from HP QC via test scripts which are then custom entry points for kicking off test execution in some other external tool which can then report verdicts to the tool.

Conformiq Designer can import requirements from the HP Quality Center and report how these requirements are covered by the model and, after generating the test suite, Conformiq Designer can synchronize the test suite with the HP Quality Center, which enables your organization to leverage the HP Quality Center quality activity management capabilities with the Conformiq Designer generated test suite. To enable connection to the HP Quality Center, an integration plug-in needs to be enabled by selecting it in the Conformiq project's properties, either as the *Requirement Synchronization connector* or as the *Test Case Synchronization connector* or as both for full utilization of integration capabilities.

The HP Quality Center integration plug-in imports the entire requirements hierarchy from the designated HP Quality Center project. Requirements are imported at the time of the model import. When the model is loaded, Conformiq Designer reports differences between requirements in the model and external requirements imported from the HP Quality Center project.

Prior to uploading generated tests to HP Quality Center, the connector automatically moves all tests that remain in the destination folders like "/Subject/TEST_CASES/FN00112/GENERATED_TESTS/DC1" to a folder in the *HP Quality Center recycle bin*. This directory is identified by the time stamp of deletion. The default location of the recycle bin is "/_Recycle Bin_/", which then can be changed with *Recycle Bin* configuration option shown in a Section below.

The integration has been implemented and tested with HP Quality Center version 9 and version 10. The integration works with all three available editions of HP Quality Center: HP Quality Center Starter Edition, HP Quality Center Enterprise, and HP Quality Center Premier.

This integration is only available in Conformiq Designer Windows builds. Also, for the

integration work HP Quality Center client must be installed on the machine where the integration is used.

7.2.1 Annotating the Model with Requirements

When annotating the model with requirements from the requirements catalog defined in the HP Quality Center, the requirement name to unique extent must be used. The requirement name contains the requirement's own name and names of all parent requirement groups beginning from the root requirement divided by a slash.

For example:

In order to refer to the requirement "8.2.1 UAS MUST inspect the method of the request" in the following requirement hierarchy:

```
Functional Requirements
Standards Conformance
  RFC 3261: Session Initiation Protocol
    8.2.1 UAS MUST inspect the method of the request
```

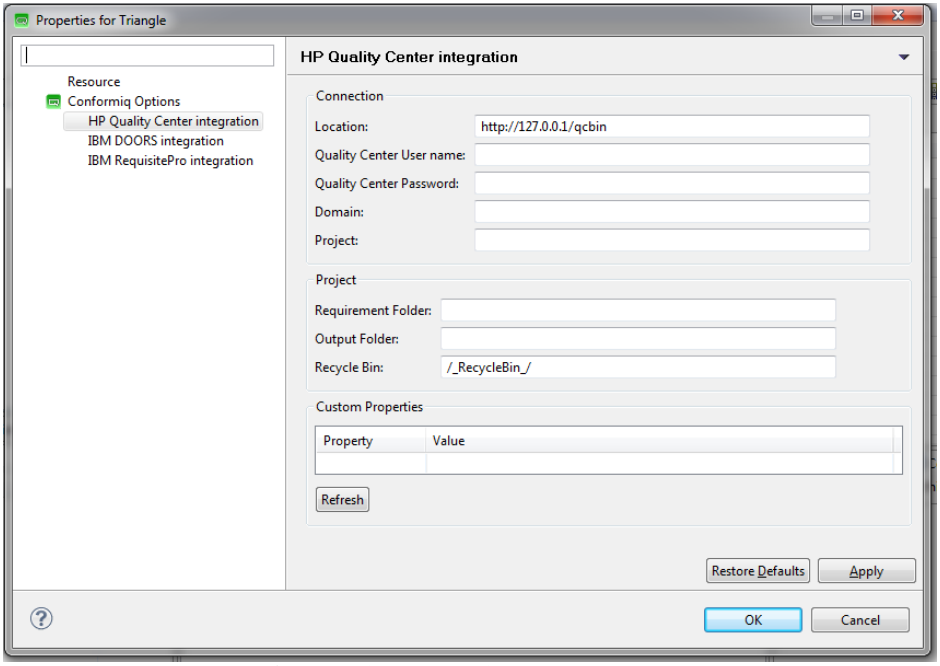
the model should be annotated with a requirement "Standards Conformance/RFC 3261: Session Initiation Protocol/8.2.1 UAS MUST inspect the method of the request". However, Conformiq Designer tries its best to find a unique match between the requirements in the model and the requirements in the HP Quality Center project by comparing unique suffixes of the requirement names. For example, the statement

```
requirement "8.2.1 UAS MUST inspect the method of the request";
```

is enough if and only if there is no other equally named requirement included in any other requirement group.

7.2.2 Configuring the HP Quality Center Connection

The following configuration options are available for configuring the HP Quality Center integration and can be modified from the "Project properties" dialog (**Project > Properties**).



Configuring the HP Quality Center connection

Location defines the HP Quality Center address used to access the project. It is the address entered in the web browser when accessing the HP Quality Center project.

Quality Center User name and **Quality Center Password** define credentials used to log in to the HP Quality Center project.

Domain defines the HP Quality Center domain assigned for the project.

Project defines the project name of the HP Quality Center project which will be used with

the Conformiq project to import requirements and to synchronize the test suite.

Requirement Folder. As HP Quality Center projects can contain thousands of requirements and often also contain a number of requirements that cannot be verified using automated test execution, this option is used to specify either of a requirement folder or folder structure, like "Testable Requirements", for limiting the reading of cataloged requirements. The connector produces an error on the console in case the folder structure does not exist. If the requirement folder is defined, Conformiq Designer will look for requirements under the requirement tree node defined by this configuration property. In particular, the requirement hierarchy defined in the model is interpreted as being relative to this folder. You should not include the path to this folder in the requirements you embed in the model.

Output Folder defines the destination folder in QC to which Conformiq uploads all generated tests, e.g., "/Subject/TEST_CASES/FN00112/GENERATED_TESTS/". By default this option is empty, which results in creating a folder for each design configuration in the "/Subject" folder of the HP Quality Center test plan. During upload, this folder is automatically extended by Conformiq with subdirectories for each design configuration, e.g., "/Subject/TEST_CASES/FN00112/GENERATED_TESTS/DC1". If the destination folder does not exist in HP Quality Center, Conformiq aborts the uploading and produces an error to the console.

Recycle Bin. As mentioned above, prior to uploading generated tests to HP Quality Center, the connector automatically moves all tests that remain in the destination folders to the HP QC recycle bin. By default the recycle bin directory is called "/_Recycle Bin_/", but this option can be used to change the default.

Because HP Quality Center allows users to customize their "Details" view with such additional fields that are usually company or even project specific, the HP Quality Center test management connector can be used to get access to a list of additional custom fields. These fields, just like the set of predefined configuration options enumerated above, then appear in the HP Quality Center configuration properties as configuration options. All the field values selected in the properties are then uploaded with each test in the test set. In addition to custom fields, Conformiq automatically fills the optional default field named

"LEGACY TOOL" for each test with the string "Conformiq Designer".

7.3 IBM Rational RequisitePro Integration

IBM Rational RequisitePro is a requirement management tool that lets teams author and share their requirements using document-based methods while leveraging database-enabled capabilities (for more information about IBM Rational RequisitePro, please point your browser to http://www-01.ibm.com/software/awdtools/reqpro/).

Conformiq can import requirements from IBM Rational RequisitePro and report how these requirements are covered by the model. To enable connection to IBM Rational RequisitePro the integration plug-in needs to be enabled by selecting it in the Conformiq project's settings as the current requirement management tool.

The IBM Rational RequisitePro integration plug-in imports the entire requirements hierarchy ignoring packages, documents and views. Requirements are imported right before the model import. When the model is loaded Conformiq Designer reports differences between requirements in the model and external requirements imported from the IBM Rational RequisitePro project.

The integration has been implemented and tested with IBM Rational RequisitePro version 7.1.

7.3.1 Annotating the Model with Requirements

When annotating the model with requirements from the requirements catalog defined in IBM Rational RequisitePro, the full requirement name must be used. The full requirement name contains the requirement's own name and names of all parent requirements beginning from the root requirement divided by a slash. Package names are not used.

For example:

In order to refer to the requirement "2.1.1 Sub-sub-requirement 1" in the following

requirement hierarchy:

```
1 Requirement 1
2 Requirement 2
2.1 Sub-requirement 1
2.1.1 Sub-sub-requirement 1
```

the model must be annotated with a requirement "Requirement 2/Sub-requirement 1/Sub-sub-requirement 1".

7.3.2 Configuring the IBM Rational RequisitePro Connection

The following configuration options are available for configuring the IBM Rational RequisitePro integration and can be modified from the "Project properties" dialog (**Project > Properties**).

Project file name defines the IBM Rational RequisitePro project file which will be used with the Conformiq project to import requirements.

User name defines the internal IBM Rational RequisitePro user which will be used to access the IBM Rational RequisitePro project.

Password defines the user password.

7.4 IBM Rational DOORS Integration

IBM Rational DOORS is a requirement management tool providing a comprehensive requirements management environment with change tracking capabilities (for more information about IBM Rational DOORS, please point your browser to http://www-01.ibm.com/software/awdtools/doors/).

Conformiq can import requirements from IBM Rational DOORS and report how these requirements are covered by the model. To enable connection to IBM Rational DOORS the integration plug-in needs to be enabled by selecting it in the Conformiq project's settings as

the current requirement management tool.

The IBM Rational DOORS integration plug-in imports the entire requirements hierarchy constituting all the modules and requirements. Requirements are imported right before the model import. When the model is loaded Conformiq Designer reports differences between requirements in the model and external requirements imported from the IBM Rational DOORS project.

The integration has been implemented and tested with IBM Rational DOORS version 9.2.

Note that the IBM Rational DOORS client needs to be installed on the same computer on which you run the Conformiq Eclipse Client user interface.

7.4.1 Annotating the Model with Requirements

When annotating the model with requirements from the requirements catalog defined in IBM Rational DOORS, the requirement name to unique extent must be used. The requirement name contains the requirement's own name and names of all parent requirement groups and modules beginning from the project divided by a slash.

For example:

In order to refer to the requirement "8.2.1 UAS MUST inspect the method of the request" in a project called "SIP" in the following requirement hierarchy:

```
RFC 3261: Session Initiation Protocol
  13.2.2.4 2xx Responses
    UAC core establishes session with ACK
```

the model should be annotated with a requirement "SIP/RFC 3261: Session Initiation Protocol/13.2.2.4 2xx Responses/UAC core establishes session with ACK". However, Conformiq Designer tries its best to find a unique match between the requirements in the

model and the requirements in the IBM Rational DOORS project by comparing unique suffixes of the requirement names. For example, the statement

```
requirement "UAC core establishes session with ACK";
```

is enough if and only if there is no other equally named requirement included in any other requirement group.

7.4.2 Configuring the IBM Rational DOORS Connection

The following configuration options are available for configuring the IBM Rational DOORS integration and can be modified from the "Project properties" dialog (**Project > Properties**).

Database host specifies the host where the IBM Rational DOORS database server is running. The default value is *localhost*.

Database port number specifies the port number used to connect to the IBM Rational DOORS database server. The default value is *36677*.

User name defines the internal IBM Rational DOORS user which will be used to access IBM Rational DOORS project.

Project name defines the IBM Rational DOORS project file which will be used with Conformiq project to import requirements.

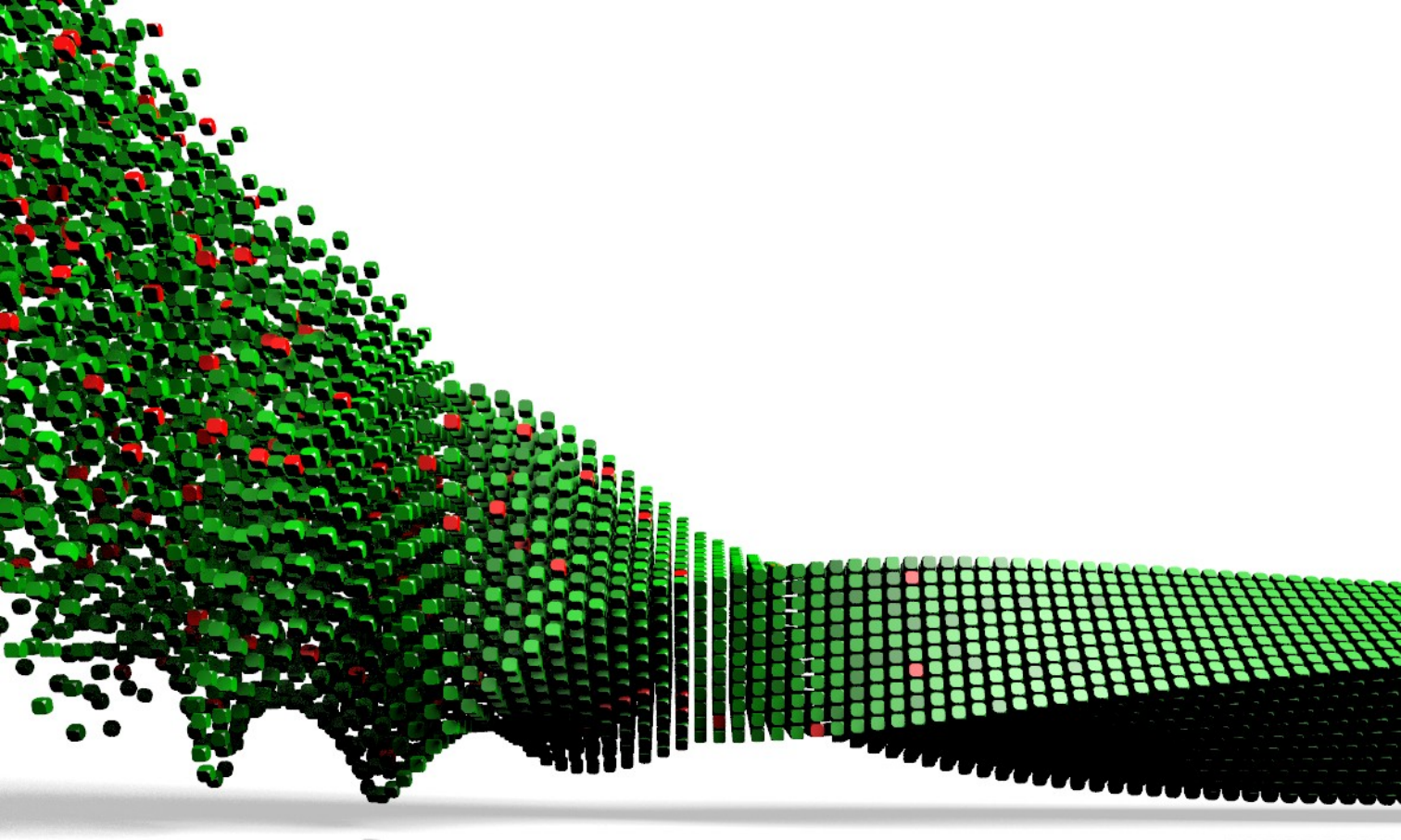
Password defines the user password.

Use requirements at all levels is used to specify whether Conformiq Designer should interpret only the "leaf requirements" or "all the requirements" (including non leaf requirements) in the requirement hierarchy as the entities to be cross checked against requirement annotations in the model.

For example, if the module in DOORS contains the following requirement structure

```
1 X
1.1 Y
```

and if the option "Use requirements at all levels" is enabled, then Conformiq Designer will interpret "X" and "X/Y" as two distinct requirements and will look for corresponding requirement annotations from the model. On the other hand, if the option has not been selected, Conformiq Designer will interpret "X/Y" as the only requirement.



8 Creating Conformiq Scripting Backends

There are software processes wherein it is beneficial to generate separate test scripts that can be stored in version control systems, maybe distributed, and executed independently afterwards. To meet this need, Conformiq provides the means for generating test scripts using configurable *scripting backends*. Simply, a scripting backend is a plugin component that is connected to Conformiq using a well-defined API. Scripting backends and open APIs enable the creation of custom output formats and the utilization of test libraries in generated test scripts to seamlessly integrate with your existing test execution environment.

These plugins can be created by the organization that employs Conformiq for testing, or they can be outsourced or, in some cases, bought as off-the-shelf software components. Conformiq is shipped with a number of scripting back-ends as mentioned in Section How to Export Test Cases, namely

- An HTML scripting backend for generating browsable HTML documents.
- A TTCN-3 scripting backend for generating test script in TTCN-3.
- A TCL scripting backend for generating test scripts in TCL.
- A Perl scripting backend for generating test scripts in Perl.

Multiple scripting back-ends can be used in parallel, they can be distributed over TCP/IP networks, and different data filters and manipulators can be added in front of the back-ends. These capabilities are provided by standard components supplied with Conformiq. The only custom components that must be created are the basic scripting backends.

The following Sections detail the process of creating custom scripting backends using Java as the implementation language and Eclipse as the development environment.

8.1 Communicating Using QML Datum Interface

The underlying test scripts generated by Conformiq Designer are sequences of timed messages. The mapping of these sequences to languages such as C/C++, TCL, TTCN-3, Perl, Python, and Java is mostly straightforward. The main task is to encode the sequence of timed messages, a sequence of QML record instances, to some specific output format. See

Sections Record Types and Input and Output for more information about QML records.

The generic datums in Conformiq Qtronic 1.X are omitted from Conformiq Qtronic 2.X and thus in Conformiq Designer there is no need for the extra step of converting generic datums to QML datums. As the models are created using QML, it is more coherent and meaningful to deal with objects that "look like" QML types.

8.2 Creating Scripting Backends in Java

A scripting backend implemented in Java is a JAR (Java Archive) file that can be used to create test scripts.

A scripting backend written in Java is a class extending the abstract base class **com.conformiq.qtronic2.ScriptBackend** from **Qtronic2PluginAPI.jar** provided in the Conformiq product. This base class contains a set of methods which Conformiq calls when there is useful information available for script generation. Scripters are synchronous, meaning that most of the methods must return a Boolean value: the methods are expected to return Boolean true if the script generation succeeds and Boolean false otherwise.

When the Conformiq Eclipse Client loads the Java plugin (see Section How to Export Test Cases for more information about loading scripting backends and exporting test cases) it first instantiates the class that implements **ScriptBackend** and then queries any configuration information that the scripter wishes to expose. (All scripters employ a common configuration API which allows custom scripters to expose hierarchical property-value pairs to the Conformiq Eclipse Client user interface. Scripting backend configuration is covered in detail in Section Exposing Scripting Backend Configuration.)

When the user wishes to export generated test cases via the scripter, Conformiq will call in sequence the methods described below:

setNotificationSink

Set notification channel that can be used to send out information to the Console

on Conformiq Eclipse Client. Called immediately after construction to set notification callback object pointer.

setMetaData

Set metadata dictionary. Return true if the plugin is capable of receiving the pointer to the metadata dictionary, otherwise false. In practice, always return true. There is a default implementation that returns true.

setConfigurationOption

Set value of a configuration option. The plugin can use this method to get access to two kinds of configuration options: (1) configuration options that are set in the Conformiq Eclipse Client user interface (f.ex. used testing heuristics and model level coverage options) and (2) user defined configuration options that are based on the XML document 'Configuration.xml' inside the JAR file of the plugin. In the case there is a subtree in the user defined configuration option, the property contains a tree in dot separated format (e.g. "dir1.dir2.item"). The return value indicates if this is an acceptable value for this property or not. E.g. if property is a TCP port number and the user enters a non-number, the plugin should return false. `setConfigurationOption()` is called for each and every available configuration option.

beginScript

Conformiq will invoke this method to indicate the beginning of the actual test script. For example this method can be used for outputting a header into the test script containing information about test generation options, script creation time, and so on.

beginCase

Conformiq will invoke this method to indicate the beginning of a test case. This method is called zero or more times after a call to `beginScript()`. For example this method can be used for outputting a header of the test case with the name of the test case. After `beginCase()` Conformiq will call the methods below so that

the scripter can render the actual sequence of steps in the test case in the selected output format.

caseID

Conformiq will invoke this method right after opening a test case. This routine can be used to set numeric "Test Case ID" defined by Conformiq Designer. This numeric ID can be used to maintain mapping from the given test case to the one in the Conformiq Eclipse Client user interface (in cases where you cannot derive the ID directly from the test case name).

caseDescription

Conformiq will invoke this method to set test case description. The test case description passed as the argument of this routine is generated from the "narrative" fragments that are used to build a narrative of what happens in a test case from the system perspective (See Section Intelligent Test Case Naming for more information about test case naming and test case descriptions).

caseProbability

Conformiq invokes this routine to set test case probability (See Section Probabilities and Priorities for more information)

testStep

Conformiq will invoke this method to indicate a single test step, i.e., a single test message either in the inbound (from the tester to the SUT) or the outbound (from the SUT to the tester) direction. As arguments to this method, Conformiq will pass the content of the message (i.e. an instance of a QML record), the name of the thread in the model that is expected to send or receive the message, the direction of the step, and finally the timestamp that is the required or expected time when the message must be sent or received.

internalCommunicationsInfo

Conformiq will invoke this method to indicate a single internal communication

step, i.e., a single message take-over between internal threads in the model. As this information is derived from the internals of the model and does not relate to external behavior, this should not affect test execution at all, so it is possible to generate valid and executable test scripts while ignoring all calls to this method. However, this method is usually used for documenting the test script (in practice the internal message take-over is encoded into a comment in the test case).

checkpointInfo

Conformiq will invoke this method to indicate that the given model-driven coverage goal has been covered. As with `internalCommunicationsInfo()`, this should not affect test execution at all, so it is possible to generate valid and executable test scripts while ignoring all calls to this method. However, if you are interested in how the test scripts are mapped to model-driven coverage you can benefit from implementing this method properly.

The following methods are invoked by Conformiq to indicate the end of a test case and finally the end of the test script:

endCase

Conformiq will invoke this method to indicate the end of a test case.

endScript

Conformiq will invoke this method to indicate the end of test script.

setConfigurationOption is also used by Conformiq Eclipse Client to pass certain additional information to scripting backends:

- **Project** gives the name of the Conformiq project from which the script has been rendered
- **Project Path** gives the file system path to the Conformiq project from which the script has been rendered

- **Lookahead Depth** gives the lookahead depth that was used to generate the test suite
- **Maximum Communication Delay** gives the communication delay that was used when the test suite was generated
- **Only Finalized Runs** tells whether test suite only contain finalized runs
- **OSI Methodology Support** tells whether test suite has been generated by applying OSI methodology
- **Require Conversion for Interoperability Testing** tells whether interoperability testing features were applied during the test generation
- **Automatic Test Case Naming** tells whether Intelligent Test Case Naming feature was used to automatically name the generated test cases
- **Enable Perturbation Support** tells whether the test suite was produced with Perturbation support
- **Conformiq Version** gives the version of the Conformiq Designer that was used to render the test suite

A Simple Scripter Backend

Here is a very simple scripting backend that simply outputs information to the console.

```
import com.conformiq.qtronic2.*;

/** An example scripter plugin for Conformiq. */
public class ExampleScriptBackend extends ScriptBackend {
    public boolean beginScript(String dc_name)
    {
        mSink.notify("info", "Beginning script: " + dc_name);
        return true;
    }
    public boolean beginCase(String tc_name)
    {
        mSink.notify("info", "Beginning test case: " + tc_name);
        return true;
    }
    public boolean checkpointInfo(Checkpoint cp, int status, TimeStamp ts)
    {
        if (status == Checkpoint.CheckpointStatus.COVERED)
        {
            if (cp.getType() == Checkpoint.CheckpointType.REQUIREMENT)
                mSink.notify("info", "Covered requirement " + cp.getName());
            else
                mSink.notify("info", "Covered checkpoint " + cp.getName());
        }
        return true;
    }
    public boolean testStep(QMLRecord datum, String thread, String port,
                            boolean isFromTester, TimeStamp ts)
    {
        StringBuffer data = new StringBuffer();
        ValueVisitor v = new ValueVisitor(data);
        datum.accept(v);
        mSink.notify("info", "Test step: " +
                     (isFromTester ? "tester" : "SUT") + " sends " +
                     data + " to " + port + " at " + ts.seconds + "." +
                     ts.nanoseconds);
        return true;
    }
    public boolean internalCommunicationsInfo(QMLRecord datum, String sender,
                                              String receiver, String port,
                                              TimeStamp ts)
    {
        StringBuffer data = new StringBuffer();
        ValueVisitor v = new ValueVisitor(data);
        datum.accept(v);
        mSink.notify("info", "Internal communication: " +
                     sender + " sends " + data + " to " + receiver +
```

```
                " via " + port + " at " + ts.seconds + "." +
                ts.nanoseconds);
    return true;
}
public boolean endCase()
{
    mSink.notify("info", "Ending test case");
    return true;
}
public boolean endScript()
{
    mSink.notify("info", "Ending script");
    return true;
}
public void caseProbability(double probability)
{
    mSink.notify("info", "Test case probability: " + probability);
}
public boolean setConfigurationOption(String property, String value)
{
    mSink.notify("info", "Set configuration option '" + property +
                " to '" + value + "'");
    return true;
}
public boolean trace(String message, TimeStamp time) { return true; }
public void setNotificationSink(NotificationSink sink) { mSink = sink; }
/** Value visitor for rendering QML values. */
class ValueVisitor implements QMLValueVisitor {
    public ValueVisitor(StringBuffer out) { mOut = out; }
    /** Visit a QML array. */
    public void visit(QMLArray a)
    {
        mOut.append("{ ");
        int n = a.getNumberOfElements();
        if (n < 1)
        {
            mOut.append("'empty array'");
        }
        else
        {
            for (int i = 0; i < n; i++)
            {
                if (i > 0)
                {
                    mOut.append(", ");
                }
                a.getValue(i).accept(this);
```

```
            }
        }
        mOut.append(" }");
    }
    /** Visit a QML boolean. */
    public void visit(QMLBoolean b)
    {
        mOut.append(b.getValue() ? "true" : "false");
    }
    /** Visit a QML number. */
    public void visit(QMLNumber n)
    {
        if (n.isBigInteger())
        {
            mOut.append(n.getBigInteger());
        }
        else
        {
            mOut.append(n.getNumerator());
            mOut.append("/");
            mOut.append(n.getDenominator());
        }
    }
    /** Visit a QML record. */
    public void visit(QMLRecord r)
    {
        mOut.append("record " + r.getName() + " {");
        for (int i = 0, n = r.getNumberOfFields(); i < n; i++)
        {
            QMLRecordField f = r.getField(i);
            mOut.append(" " + f.getName() + ": ");
            QMLValue v = f.getValue();
            if (v != null)
            {
                v.accept(this);
            }
            else
            {
                mOut.append("null");
            }
        }
        mOut.append(" }");
    }
    /** Visit a QML string. */
    public void visit(QMLString s)
    {
        if (s.getValue().equals(""))
```

```
            {
                mOut.append("\"\"");
            }
            else
            {
                mOut.append("\"" + s.getValue() + "\"");
            }
        }
        /** Visit a QML optional type. */
        public void visit(QMLOptional p)
        {
            if (p.isPresent())
            {
                mOut.append("optional: ");
                p.getValue().accept(this);
            }
            else
            {
                mOut.append("'omitted field'");
            }
        }
        private StringBuffer mOut = null;
    }
    private NotificationSink mSink = null;
}
```

8.3 Exposing Scripting Backend Configuration

All scripting backends employ a common configuration API which allows custom scripters to expose hierarchical property-value pairs in the Conformiq Eclipse Client user interface.

The scripter defines these property-value pairs in an XML document. This information will be handled and presented by the Conformiq Eclipse Client user interface and once the scripter has been configured according to the user's wishes, the configuration will be passed to the scripter via calls to `setConfigurationOption()` defining the property and the user defined value.

setConfigurationOption

Set the value of a configuration option. A scripting backend can use this method to

get access to two kinds of configuration options:

(1) Configuration options that are set in the Conformiq Eclipse Client user interface (e.g. used testing heuristics and model level coverage options).

(2) User defined configuration options that are based on the XML document 'Configuration.xml' inside the JAR file of the scripter.

In the case of a sub-tree in the user defined configuration option, the property contains a tree in dot separated format (e.g. "dir1.dir2.item"). The return value indicates if this is an acceptable value for this property or not. E.g. if the property is a TCP port number and the user enters a non-number, the scripter should return false.

XML document

A scripter defines an XML document called **Configuration.xml** that is placed into the root of the scripter JAR file. This document can define an arbitrary number of hierarchical options. After reading in this document, Conformiq Eclipse Client will show the options in the **Plugin Configuration Wizard** (See Section How to Export Test Cases). For example, the scripter which generates a test script which contains *hooks* (function calls to user-written code) can define two subgroups of options: one which contains an output file and another which contains hook related options. The scripter is informed about a user defined configuration (defined by the using Plugin Configuration Wizard) via calls to `setConfigurationOption(String property, String value)`, where the property contains hierarchical structure separated with dots, e.g. "Output.Generated file" with value "C:\TEMP\MyOutput.tc".

This example defines two groups, "Output" and "Hooks". The Output group contains the "Generated file" property where the user of the scripter enters the filename of the output file. The "Hooks" group defines the start and end hook for both test cases and test scripts. The user can, for example, set "Testcase start hook" to value "mymodule.startSUT();" and then the scripter generates test scripts where each test case starts with a "startSUT" call from "mymodule".

```
<?xml version="1.0" encoding="UTF-8"?>
<configuration>
 <tree category="Output">
  <option property="Generated file" value="out.xxx" kind="file"/>
 </tree>
 <tree category="Hooking">
  <option property="Use hooking" value="true" kind="boolean"/>
  <option property="Testcase start hook" value=""/>
  <option property="Testcase end hook" value=""/>
  <option property="Testscript start hook" value=""/>
  <option property="Testscript end hook" value=""/>
 </tree>
</configuration>
```

Valid XML documents can contain an arbitrary number of options as defined by the following *Document Type Definition*:

```
<!ELEMENT configuration (option|tree)*>
<!ELEMENT tree (option|tree)*>
<!ATTLIST tree category CDATA #REQUIRED>
<!ELEMENT option EMPTY>
<!ATTLIST option property CDATA #REQUIRED>
<!ATTLIST option value CDATA #REQUIRED refresh CDATA #IMPLIED>
<!ATTLIST option kind (boolean|file) #IMPLIED>
```

The "kind" field in an option is used to define the dialog widget that the Conformiq Eclipse Client will use.

file

This will make a file dialog that displays a dialog window from which the user can select a file. This is useful for defining the output file, for example.

boolean

This will make a check box that can be selected (for true) or not (for false)

8.4 Preparing Eclipse Workbench

The recommended way of building Java plugins is to use Eclipse. This and the following sections detail the process of building Conformiq Java scripting backends using Eclipse as the development environment. For more information about Eclipse and Java development in Eclipse, please refer to the *Java Development User Guide* that is part of the Eclipse distribution.

The first step is to verify that Eclipse is properly set up for Java development i.e. the JRE (Java Runtime Environment) installation.

1. On the main menu bar, select **Window > Preferences...** and select **Java > Installed JREs** page to display the installed JREs. Confirm that a JRE has been detected by Eclipse and it should appear with a mark in the list of installed JREs.
2. On the Preferences Wizard, select **Java > Compiler** and set **Compiler compliance level** to **6.0**.
3. In order to automatically build the Java code, select **General > Workspace** page to display Workspace related preferences. Confirm that the **Build automatically** has been checked.
4. Click **OK** to confirm the changes.

8.5 Creating Java Project for Scripting Backends

Once Eclipse has been configured properly, we can proceed into building a Java project for the plugin. The following steps detail this process.

1. On the main menu bar, select **File > New > Project...**. This will open the **New Project** wizard.
2. Select **Java Project** and click **Next** to launch the **New Java Project Wizard**.
3. Enter a name for the project and click **Finish**.

Once the project has been created, click the newly created project in the Project Explorer

view and select **Properties** from the drop down menu.

1. From the **Properties for ...** Wizard, select **Java Build Path**.
2. Add **Qtronic2PluginAPI.jar** to the build path by selecting **Add External JARs** and finally click **OK**.

Note that the default installation path of Conformiq is changed in version 4.2.0, therefore if you have an existing Eclipse workspace and project for your scripter backend and you have upgraded from an earlier version of Conformiq Qtronic to 4.2.0 (or newer) the location of API jar needs to be updated to point to the new location.

Before creating the actual implementation of the scripting backend, we will create the configuration file for the scripting backend explained in Section Exposing Scripting Backend Configuration.

1. Select the newly created project in Project Explorer and select **New > File** from the drop down menu.
2. Enter **Configuration.xml** as the name of the file and click **Finish**. Note that this file must be located in the root of the project so that when the scripter is exported as a JAR archive, the Conformiq Eclipse Client is able to find the configuration file.
3. Select the **Configuration.xml** file in Project Explorer and select **Open With > Text Editor**. This will open a text editor that can be used to enter the configuration in XML format as explained in Section Exposing Scripting Backend Configuration.

Next we create the *concrete* class that implements the abstract class **ScriptBackend**.

1. Select the newly created project in Project Explorer and select **New > Class** from the drop down menu.
2. Enter a package name in the **Package** field.
3. Enter the name of the class that implements the **ScriptBackend** in the **Name** field.

Java convention is to name this class with a Capital letter.

4. Make sure that the **public** modifier is set.
5. Enter **ScriptBackend** as the **Superclass**.
6. By selecting **Inherited abstract methods**, Eclipse will generate for you a stub file with all the methods that need to be implemented. Naturally, these stub methods are not abstract. Make sure that you do not generate the **public void main** method.
7. Click **Finish**.

Next you will need to actually implement the methods. A very simple example is given in the Section Creating Scripting Backends in Java. Once the scripter has been implemented, we will need to generate a JAR file that will contain the compiled byte code which is the topic of the next Section.

When you allow Eclipse to automatically generate stub implementations for inherited abstract methods, you need to change the return values from *false* to *true* as the scripting backend API uses the return values to verify that the scripting backend was able to successfully complete the given operation. If the return values are left to *false*, the script rendering is aborted.

8.6 Creating Scripting Backend JAR

Once the scripting backend has been developed and the Java source files have been successfully compiled, we need to export the implementation as a JAR file.

1. Select the Java project in Project Explorer and select **Export** from the drop down menu. From the **Export Wizard**, select **Java > JAR file** and click **Next**.
2. Select the project that you are exporting as a JAR archive if it has not been already selected and select all the files from the right hand side view.
3. Enter a name for the JAR file to be exported into the field named **Select the export**

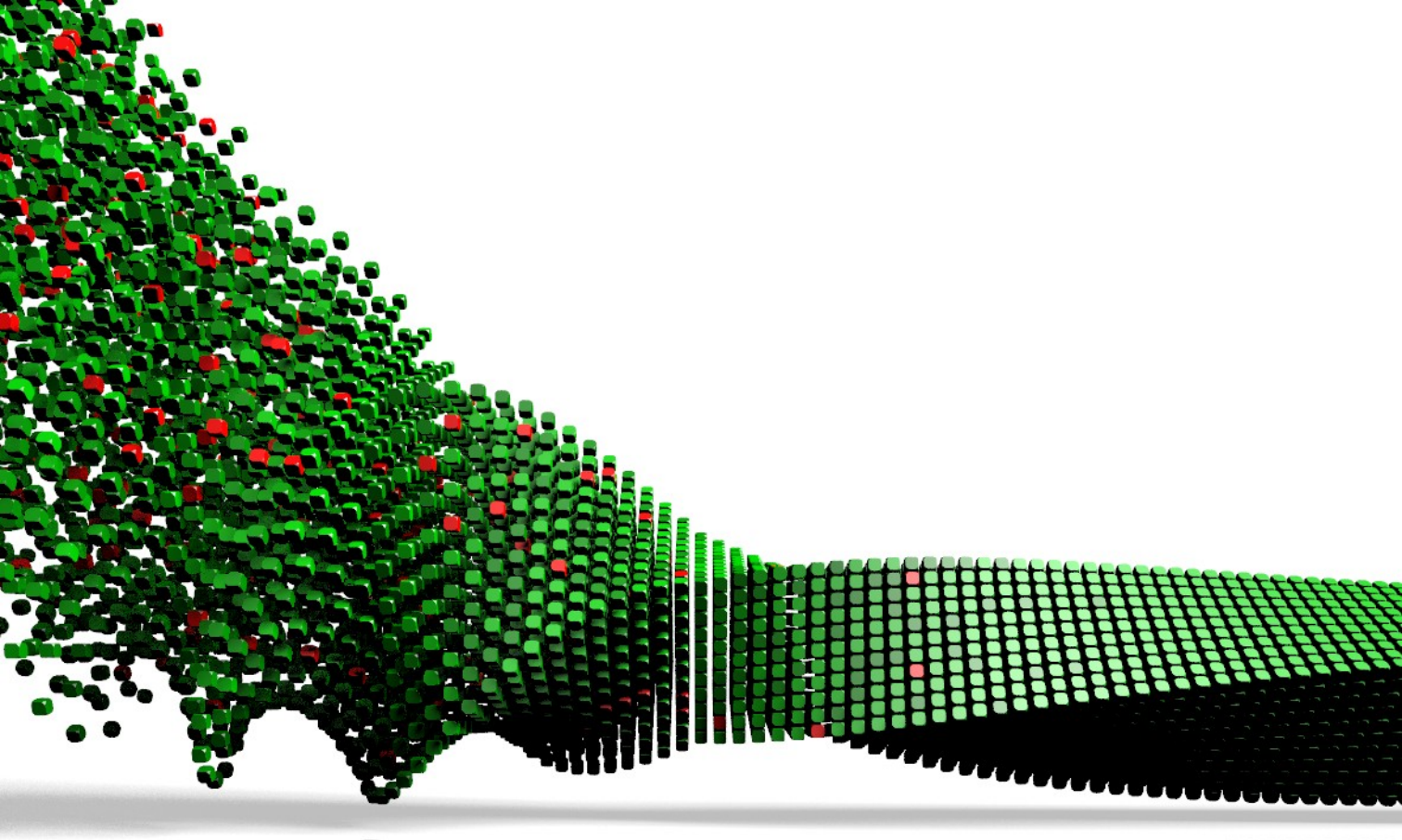
destionation: and click **Finish**. This will generate the JAR file to the location you specified.

You can then use this scripter as explained in Section How to Export Test Cases.

8.7 Debugging Scripting Backends

Scripting backends can be debugged using the **Error Log** view that captures all the warnings and errors logged by the QEC. This view is available under **Window > Show View > Error Log**. Full details about a particular error event can be viewed in the *Event Details* dialog by double-clicking on a particular entry or selecting **Event Details** from the context menu of that entry. The details contain information about exception stack trace etc. The information in the details view can be copied on to the clipboard by pressing the button with the clipboard image.

Note that you need to install the *PDE* component (http://www.eclipse.org/pde/) to Eclipse in order to see Error Log. PDE is included in most of the Eclipse packages by default. Conformiq recommends using *Eclipse Classic* which contains this component.



9 Support and Troubleshooting

Conformiq tools have been constructed following high quality standards.

Regardless of this, there are situations where you may find the software performing poorly or malfunctioning. This can be caused by one of the following reasons:

1. There can be a programming defect in the Conformiq product itself.
2. You may have tried to push Conformiq Designer beyond its natural categorical or quantitative limits.
3. The documentation provided with the tool could have created misconceptions about the behavior of the tool.

We encourage you to follow the guidelines below when you encounter a problem using of Conformiq tools.

9.1 Troubleshooting Guidelines

If you encounter problems with using Conformiq, please follow the troubleshooting guidelines given here. If the problems cannot be resolved using these guidelines, please contact Conformiq technical support (support@conformiq.com).

9.1.1 Troubleshooting QEC

In order to troubleshoot Conformiq Eclipse Client installation related problems, please refer to Section Checking the QEC Installation.

A known problem with Eclipse is that it is resource intensive. In case you are experiencing slow performance with QEC, Java heap space, or *OutOfMemoryExceptions* errors, consider modifying the virtual machine arguments for the Java virtual machine. This will provide more memory for Eclipse to operate.

The heap space size can be set using the following commands:

- The **-Xms** setting controls the initial size of the Java heap. Properly tuning this parameter reduces the overhead of garbage collection in the Conformiq Eclipse

Client.

- The **-Xmx** setting controls the maximum size of the Java heap. Properly tuning this parameter can reduce the overhead of garbage collection in the Conformiq Eclipse Client.
- The **-XX:PermSize** and **-XX:MaxPermSize** settings are used to control heap space that hold reflective data of the VM itself such as class objects and method objects.

In order to modify the JVM arguments, go to your Eclipse installation directory and edit the "eclipse.ini" file (when running the standalone version of the Conformiq Eclipse Client user interface, go to the Conformiq installation directory and open the "QEC/Conformiq Client.ini" file) as follows:

The recommended configuration options are shown below:

- When using moderate size models
  - For a machine with 2048 MB of RAM: `-Xms256m -Xmx1024m`
  - For a machine with 3072 MB of RAM: `-Xms256m -Xmx1536m`
  - For a machine with 4096 MB of RAM: `-Xms256m -Xmx2048m`
  - For machines with more RAM, adjust to fit your preferences.
- When using large models
  - For a machine with 2048 MB of RAM: `-Xms512m -Xmx1536m`
  - For a machine with 3072 MB of RAM: `-Xms512m -Xmx2048m`
  - For a machine with 4096 MB of RAM: `-Xms512m -Xmx2048m`
  - For machines with more RAM, adjust to fit your preferences.

Note that the maximum heap size set via **-Xmx** on 32-bit Windows is limited to roughly 1.2 - 1.5 GB. There are two reasons for this. One is that the 32-bit

Windows provides a process with a 4 GB address space, where the lower 2 GB out of this is referred to as the user address space. This is the amount of space available for use by the JVM. This user address space must contain certain operating system DLL's and additional DLL's. In the remaining space, the JVM must load additional DLL's for use. The second is that JVMs have required a contiguous memory space for the Java heap for efficiency reasons, which causes the maximum Java heap size to be limited by DLLs loaded into the process address space.

Note that it is recommended to have at least 2048 MB of memory on the machine running the Conformiq Eclipse Client. See Section System Requirements for more system requirements and recommendations.

For example, on a machine with 2048 MB of RAM, the configuration file would have the following content when using large models:

```
-vmargs
-Dcom.sun.CORBA.transport.ORBTCPReadTimeouts=1:60000:300:1
-Djava.net.preferIPv4Stack=true
-Xms512m
-Xmx1536m
```

Eclipse will pass these arguments to JVM when you start Eclipse again.

9.1.2 Performance Problems

It could happen that the user tries to push Conformiq Designer beyond its natural categorical or quantitative limits. Please consult *Modeling Techniques* and *Modeling Best Practices* documentation provided by Conformiq to overcome and work around some of the performance problems. Here are some very basic actions that you can take when encountering performance problems:

- Use as low *Lookahead Depth* from *Conformiq Options* as possible. Recall that the *Lookahead Depth* is used to control the exhaustiveness of the test generation. Selecting values from the left correspond to lower amounts of CPU time used — having too high a value can cause very high offline script generation times. In case that it is relatively well understood by the engineer that which parts of the model require greater lookahead values, the lookahead can also be increased locally using `cq_increase_lookahead()` construct described in Section Miscellaneous Functions.
- When developing models incrementally, it is also advised to disable the 'Only Finalized Runs' option. It is also recommended to disable calls to `incomplete` and `complete` while incremental model development.
- Experiment with different combinations of *model coverage options*.

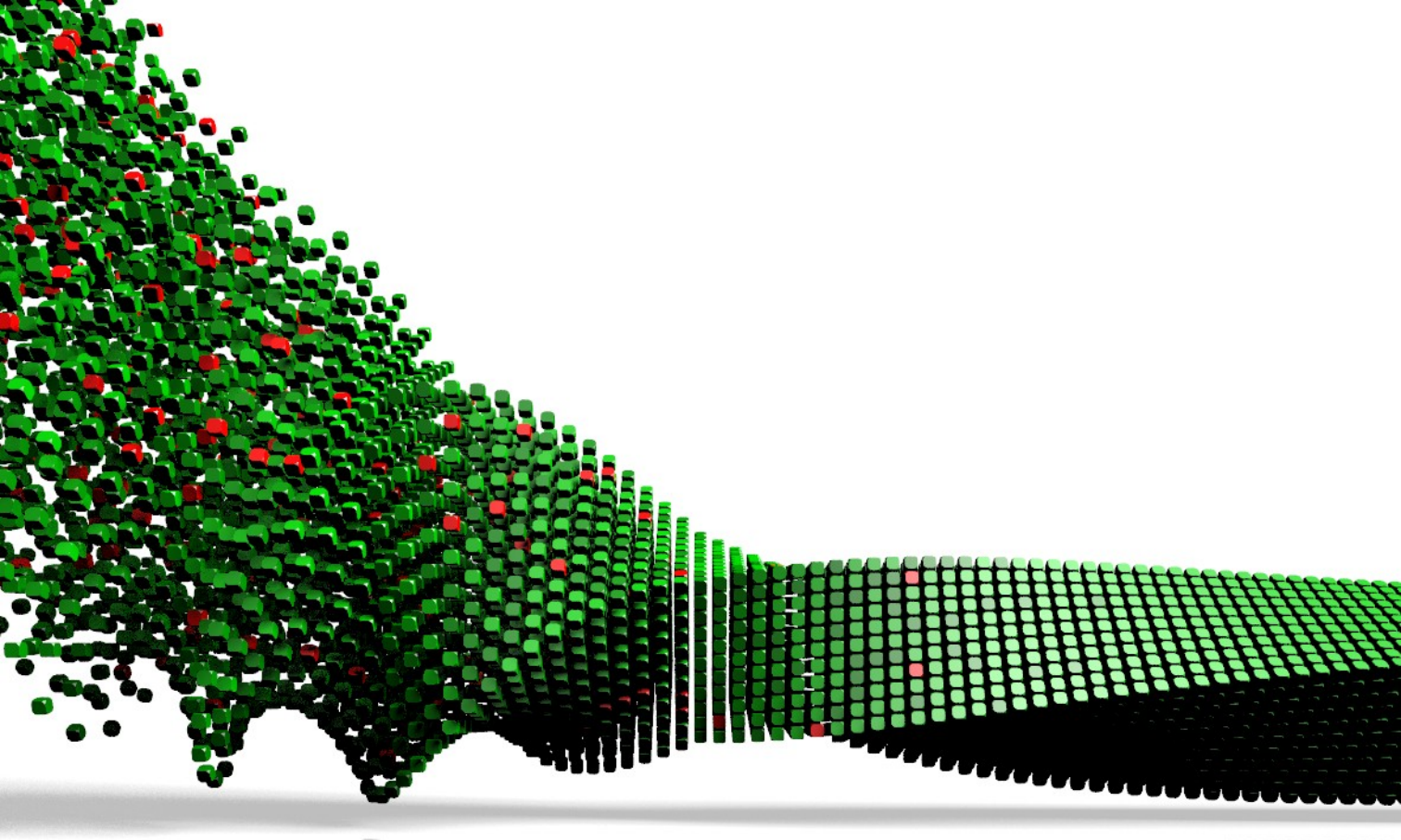
9.2 Reporting Problems with Conformiq

If you fail to resolve the problem or the problem is related to the tool itself, please contact Conformiq technical support (support@conformiq.com). When reporting problems, please provide as much information as possible:

- Provide details about your system.
  - Conformiq version
  - Operating system and version number
    - In Linux, also provide information on libc, libstdc++, and gcc versions.
  - Eclipse version
  - Conformiq licensing details
- Provide a detailed list of steps that lead to the occurring problem.
- If possible, provide the full Conformiq project with model files and test design configurations. The Conformiq project is stored under the Eclipse workspace in

the file system.

- If the problem is related to the Conformiq Eclipse Client, provide information available in the *Error Log* view which is available under **Window > Show View > Error Log**. Full details about a particular error event is available in the *Event Details* dialog by double-clicking on a particular entry or selecting *Event Details* from the context menu of that entry. The details contain information about exception stack trace etc. Copy the information in the details view on to the clipboard by pressing the button with the clipboard image and provide this information in the problem report.



A Conformiq Release Notes

Conformiq is a revolutionary solution for true design model driven test and quality assurance automation. It enables automated, thorough and cost-efficient testing of complex systems.

A.1 Download and Install

You can try Conformiq hassle-free. Evaluation license generation is automatic, so you do not need to be in contact with our sales personnel at all to start evaluating Conformiq. Conformiq binaries are available for Linux and Windows for evaluation.

Step 1 — Download Conformiq

Conformiq Evaluation can be downloaded from
http://www.conformiq.com/downloads/

Step 2 — Obtain Evaluation License Automatically

In order to obtain an evaluation license you must provide us with your contact details and information about your test design automation needs on http://www.conformiq.com/getlicense.php. An evaluation license will be sent to the e-mail address you provide which must be your **corporate email address**. By requesting the license you allow us the right to use your e-mail address for our legitimate business purposes, including but not limited to discussing the evaluation process with you.

Step 3 — Install Conformiq

Install Conformiq on your target machine. On Windows XP and Vista, execute the installer you have downloaded. On Linux, unpack the gunzipped TAR file and run "install.sh" in the directory you unpacked. Conformiq Designer is a client-server architecture where test generation happens on the Conformiq Computation Server while the user uses a client-side, Eclipse-based working environment to create the model and define test design requirements. In order to install Conformiq Eclipse Client as an Eclipse plugin, Eclipse 3.4 (Ganymede) or newer must be installed beforehand. The recommended package is Eclipse Classic.

Step 4 — Activate Conformiq

When you start Conformiq Eclipse Client, configure it to use the evaluation license as follows

- Select **Window > Preferences** in the main menu of Conformiq Eclipse Client. This will open the Preferences wizard.
- Select **Conformiq > Licensing** in the Preferences wizard. This will open the Conformiq License Management view.
- Select **Evaluation License** and provide the evaluation code you received via e-mail.

A.2 Conformiq 4.4.2

Release date: December 22nd, 2011

A.2.1 What's New or Changed

- Introduced support for utilizing the local computation resources when accessing a remote computation server. This option can be tuned so that the number of test generation slave processes allocated on the local machine can be limited or alternatively disabled altogether. See Section How to Configure Conformiq Eclipse Client for more information about this feature. A known shortcoming of this feature is that if you have used local computation services (ie you have used 'Local computation server' or you have selected 'Use additional CPUs from this node') when changing the Conformiq computation setting, you may need to manually terminate the local computation services now.
- Introducing a selection of new scripting backends
  - Introducing OpenDocument scripting backend that saves the test plan in ODT or OpenDocument format. ODT (http://en.wikipedia.org/wiki/OpenDocument) is an XML based format for representing word processing documents and is directly supported in word

processing tools such as OpenOffice and MS Word (support was released in Word 2007 SP2). See Section How to Use OpenDocument Scripting Backend for more information.

- Introducing JUnit scripting backend that saves the test plan in directly executable JUnit format. JUnit is a simple, open source framework to write and run repeatable tests in the Java programming language. It is an instance of the xUnit architecture for unit testing frameworks. See Section How to Use JUnit Scripting Backend for more information.
- Introducing QTP scripting backend that saves the test plan in QTP or QuickTest Professional format. HP QuickTest Professional is an automated testing software that performs functional and regression testing. It works by identifying the objects in the application user interface or a web page and performing desired operations. QTP uses VBScript scripting language to specify the test procedure and to manipulate the objects and controls of the application under test. The QTP scripting backend creates the actual executable script in VBScript format while it creates a full QTP project that can be then opened and executed in HP QuickTest Professional. See Section How to Use QTP Scripting Backend for more information.
- Introducing TestPlan scripting backend that saves the test plan in HTML format in an alternative format from the HTML Scripting Backend. The documentation generated by the TestPlan scripting backend can be customized by editing the "plan.js" file (that gets automatically generated the first time the scripter is executed). See Section How to Use TestPlan Scripting Backend for more information.

- Improvements to detection of potentially conflicting `require` statements - now the Conformiq Designer algorithm is slightly more aggressive and can report conflicting require statements that previously were not reported
- Incremental test generation has been fixed so that the core now always expands the same prefix of the model state space. This fixes the issue where the end user

received different coverage when using existing test assets and when generating tests from a clean start. Note that this requires more computation, so it also means that the incremental analysis is not as fast as it has been in the past.

- The handling of checkpoint notifications has been optimized. This has a very positive impact on the overall performance of the tool when there are numerous checkpoints and when you are using a remote computation server.
- Enhancements and updates to the handling of Use Cases:
  - A misbehavior in the tool where the use cases contained old and invalid data values has been fixed.
  - An issue with failing use case tracking where the use case contained data with optional field values has been fixed.
  - A problem where only one of the selected Use Cases were deleted when user requested to delete all of them has been fixed.
  - A problem where the Use Case editor represented floating point values incorrectly has been fixed.
- The HP Quality Center connector has been enhanced in a number of ways (See Section HP Quality Center Integration for more information):
  - Error reporting has been improved
  - A problem where the full path to a requirement folder did not operate properly has been fixed
  - Extended and enhanced the handling of custom properties
- Enhancements and updates to the intelligent test case naming feature:
  - A problem where the tool generated a new name for an existing valid test asset even if the model had not been changed has been fixed.
  - Capitalizations are no longer eliminated from the narrative fragments. As a convention, the narrative should start with a lower case letter unless a proper

noun is the first word in the narrative.

- Test case description in the Test Case List View can be now be copied to the clip board and the corresponding GUI element can be now resized.

- QML model compiler has been enhanced:
  - A problem with incorrect handling of type hierarchies in the QML compiler has been fixed.
  - A problem where the QML compiler previously invalidly rejected a model that contained a user defined classifier with same name as in the QML library has been fixed.
  - A problem where the QML compiler previously invalidly rejected a model that had a `belongs_to` statement with array references within it has been fixed.
- The handling of requirements in included state charts has been fixed so that the QML compiler does not reject a model where a requirement is placed to a state machine that is included to a multiple states. The requirements in the included state charts are not augmented with a text fragment that identifies the state name where the given state chart is included. This effectively keeps the requirements globally unique but at the same time introduces issue with requirements tracking
- The lookahead and maximum communication delay options in Conformiq project properties can be given a discrete value and the user sees the value when the knobs are turned.
- Enhancements to the Excel scripting backend:
  - Added support for arrays and inner records to Excel scripter
- Enhancements and updates to the Model Debugger:
  - A problem where the Variables view in the Conformiq Model Debugging perspective showed the type of a floating point value incorrectly as `long` has been fixed.

- The problem where the Conformiq Eclipse Client incorrectly deleted existing files from the file system when the user canceled 'New Project Wizard' has been fixed.

A.3 Conformiq 4.4.1

Release date: October 11th, 2011

A.3.1 What's New or Changed

- Release of Conformiq Designer 4.4.1 has introduced **Priority Based Test Generation** which allows the end user to prefer certain behaviors over others, thus emphasizing the importance of certain model parts by carefully placing priorities and probabilities to the model. Priorities and probabilities are placed to the model via priority and probability keywords (which have been in the QML language for quite some time, but before, the accumulated priority mass was used only for sorting the test cases). See Section Probabilities and Priorities for more information.
- The **Use Case** feature introduced in Conformiq 4.4.0 has been enhanced in a number of ways (See Section Defining a Use Case for more information):
  - The *Use Case Editor* has been extended with UNDO operation to ease up the creation of the use cases.
  - The problem where activation of a Use Case caused the overall coverage to decrease has been fixed.
  - Stack overflow has been fixed in the *Use Case Editor*
- **Conformiq Model Debugger** has been extended and enhanced (See Section Single Stepping Debugger for more information):
  - The *Execution Trace View* has been extended with "Run to Here" debugger action that has the same behavior as the "Run to Here" debugger action in the *Model Browser* but, in addition, allows more fine grained selection of the actual

location where the Conformiq Model Debugger is executed.

- Support for sorting the variables alphabetically in ascending or descending order based on the variable name and variable type has been added to *Variables* view. This eases the task of locating an interesting variable in the view especially when the number of variables is large.
- *Variables* view has been extended with support for displaying integral values in binary, octal, and hexadecimal, in addition to decimal values.

- **IBM / Telelogic Rhapsody model importer** has been extended with support for importing composite states and orthogonal regions
- **Intelligent Test Case Naming** has been enhanced to name certain tests that previously could not find a name automatically, therefore defaulting to "Unnamed <n>".
- The **upload test cases to a third-party test management tool** has been separated from the test generation action. Upload test cases can be now triggered separately by clicking *Upload Tests* in the Conformiq Eclipse Client. This will make the work flow more intuitive and robust allowing the user to analyze the test generation results in the Conformiq Eclipse Client before uploading the results to test management tool, i.e., avoiding the situation where tests that have not been reviewed would be uploaded to the test management tool. When working with HP Quality Center integration, for example, during each upload Conformiq Designer will create a destination folder in QC for each design configuration and upload all applicable tests. See Chapter Test and Requirement Management Tool Integrations for more information.
- The **requirement management tool** integrations have been enhanced with improved console reporting on requirement mismatches and a possibility to suppress warnings.
- **HP Quality Center integration** has been significantly enhanced (See Section HP Quality Center Integration for more information)

- Configuration option for specific QC project folder structure in HP Quality Center integration settings has been introduced to the requirement management tool connector.
- Configuration option for suppressing of warnings in HP Quality Center integration settings has been introduced to the requirement management tool connector.
- Configuration option for modifying the QC destination folder in HP Quality Center integration settings has been introduced to the test management tool connector.
- Ability to specify additional custom fields to *Details Tab* in *Test Plan View* of HP Quality Center has been introduced.
- The work flow has been updated to move the existing tests in destination directory to user defined recycle bin prior to upload of tests.
- The basic documentation in *Description tab* of *Details tab* in *Test Plan View* has been enhanced.
- The test design output in *Design Steps tab* in the *Test Plan View* has been improved.

- Certain cases of non deterministic test generation have been identified and fixed in the core test generation algorithm.
- The **distributed test case generation algorithm** has been improved by making it more scalable. The update algorithm distributes the test generation work more aggressively than before, attempting to utilize the test generation slaves as much as possible.
- The robustness of the Conformiq Computation Server on Linux has been increased in situations where the system is running out of memory at which time the default behavior of the Linux kernel is to start to kill processes heuristically. The updates to the Conformiq Computation Server decreases the "badness score"

of the process that accepts test generation tasks to the server while increases the score of huge test generation tasks, therefore signaling to the Linux kernel that it is more important to keep the Conformiq Computation Server alive that potentially serves more than one end user than a single test generation task.

- An **Excel scripting backend** is now available to render tests textually in a Microsoft Excel worksheet. This backend has been inspired by and designed for use in manual test execution but can also be used for test documentation or communicating tests to stakeholders, such as Business Analysts, who are not able to understand the HTML format. The output produced by this backend is highly configurable. Users can customize the default mapping to prose in an extensive mapping file. See Section How to Use Excel Scripting Backend for more information.
- The **TTCN-3 scripting backend** has been updated to generate more test documentation. In addition, TTCN-3 default altsteps are now generated in their own file and the handling of unexpected messages has been extended. See Section How to Use TTCN-3 Scripting Backend for more information.
- The **QML language parser** has been enhanced to report all parsing errors located in a single compilation unit at once instead of merely the first one.
- The **QML language lexer** has been enhanced in number of ways.
- The performance of the Conformiq Eclipse Client has been improved
- The Flexera Publisher licensing mechanism used by Conformiq has been updated to a newer version

A.4 Conformiq 4.4.0

Release date: June 14th, 2011

A.4.1 Use Case Support

Introducing ability to specify **use cases** separately from the modeled behavior – sometimes also referred to as test purposes. These use cases represent partial or full sequences of messages exchanges with restrictions on data based on the specified system interface and they are used to describe a particular model behavior, i.e., a run of the model.

A use case in Conformiq describes essentially high level, usually partial I/O sequence that a system under test (i.e., the black box) is expected to reproduce. For each message in such a sequence the message type and the port (as specified in the system interface specification of the model capturing the system operation) and expected time stamp have to be specified. By default any message contents are accepted for a message but can be refined by further constraining the message field values to specific values. Secondly, one or more so called "gaps" can be inserted into any point at these sequence to express that any messages can arrive or be sent on any port before the next message in the sequence occurs in a generated test. Besides the reuse of the system interface specification, use case specification is completely independent of the specification of functional behavior, i.e., it is possible to specify use case or (partial) message sequences that do not comply or violate to specified system operation.

Use cases can be used for example for steering the test generation and for validating models against certain criteria.

See Section How to Create Use Cases for more information about use case support.

A.4.2 Perturbation (Generation of Non Standard Data Distribution)

Perturbation is a Conformiq Designer feature that allows you to generate tests with non-trivial data distribution. When the perturbation support is enabled, the data values that the tool selects are chosen in a non-trivial fashion, so for example instead of selecting value 0 for an integer field the tool may choose to select -7 and your previously empty string may look like "¤)/=)&". The selection is always deterministic, however, so if you clean your test database and regenerate the tests the tool will generate exactly the same test suite, with the

same test cases and with the same test data.

See Section Perturbation for more information.

A.4.3 Intelligent Test Case Naming

Introducing a feature that automatically assigns a meaningful name for each test case based on the model parts that the given test case covers.

See Section Intelligent Test Case Naming for more information.

A.4.4 Improved Detection of Parsing Errors

Detection of syntactic errors in the QML language parser has been significantly improved, which is a key feature of the QML compiler. The improved parsing algorithm reports the first encountered syntactic error in the model, provides a list of syntactic structures that the algorithm expected at the given point, and terminates after this.

A.4.5 Command Line Interface for Batch Mode Execution

Conformiq Designer includes support for running test generation from the command line instead of opening the Eclipse user interface, thus allowing the user to run the tool without a graphical user interface. The console based user interface directly utilizes the resources in an existing Conformiq project in an Eclipse workspace.

See Section Command Line User Interface for more information.

A.4.6 Other New Features

- Introducing a feature for duplicating existing test design configurations. See Section How to Create Test Design Configurations for more information.
- Introduced global test generation options for automatically stopping immediately upon reaching (a) full overall coverage and (b) full requirement coverage. See

Section How to Configure Global Testing Parameters for more details.

- Eclipse *Error Log* view has been bundled to RCP version of the Conformiq Eclipse Client.
- QML language has been extended with a new convenient function for receiving a certain kind of message from an interface. See Section Input and Output for more information.
- QML library has been extended with a predefined `Queue` container data type. See Section Containers for more information.
- `prefer` can be used to set preferred field values for QML unions in addition to QML records.
- Scripting backend API has been extended with **public void caseID(int id)** routine for retrieving test case identitier of the given test case as defined by the Conformiq Designer.

A.4.7 Other Updates

- Calculation and checking of *node identifier* that is used by the licensing subsystem has been made more robust.
- Refresh interval of floating licenses can be selected by the user instead of having the hard-coded 30 minutes checkout period (See Section License Management in Conformiq for more information)
- Internal component of Conformiq Computation Server for calculating data dependencies has been optimized making test generation faster, especially with models containing a lot of data manipulation.
- Conformiq project database handling in Conformiq Eclipse Client has been optimized for memory and speed.
- The QML model compiler has been heavily optimized for memory and speed.

- The communication between Conformiq Eclipse Client and Conformiq Computation Server has been optimized making the communication faster and more robust.
- Numerous fixes and small optimizations to Conformiq Eclipse Client, Conformiq Computation Server, and to Conformiq Modeler.
- Sporadic Conformiq Computation Server crashes on Linux caused by a 3rd party library have been fixed.
- Eclipse Error Log View has been added to Conformiq Eclipse Client RCP edition to ease debugging of scripting backends.
- Transition layout algorithm of Conformiq Modeler has been enhanced to avoid situations where nearby transitions are coalesced even when here is room for spreading them.
- Reintroducing predefined `trace()` function to QML that can be used to conduct ad-hoc *printf debugging* and for example to collect some very elementary information about how the test generation progresses. See Section Miscellaneous Functions for more information.

A.4.8 Known Problems

QML Language Compiler

- QML compiler does not report syntax errors from all the compilation units; if there are syntax errors for example in multiple transitions strings, only one of them are reported during the compilation.
- Various error messages produced by the QML compiler are confusing.
- Final variable declarations cannot be initialized in constructors, but the initialization must be carried out always in the variable declaration.
- Predefined `StateMachine` cannot be inherited in a class contained in another

class; doing so will cause the Conformiq test generation engine to report a spurious model defect.

- In certain situations, the compiler will not fail a model in which a non static class or record is accessed in static context even though it should. Also, not all legal variable references in static context are accepted by the QML compiler while they should be.
- `requirement` keyword cannot be used in template functions as the instantiation of a template function causes compiler to report that the requirement string is not globally unique.
- QML compiler, in certain situations, fails to resolve template arguments causing the compilation to fail.
- Non trivial constant expressions are not accepted by `prefer` statements.

Conformiq Test Generation Engine

- The Use Case Editor misses UNDO functionality
- When perturbation support is turned on, all the values in the test suite are candidates for value perturbation (naturally within the valid value domain). This also means that the timestamps of test steps can be perturbated, which can be unwanted in certain situations and currently there is no option in the Conformiq to turn off perturbation of timestamps.
- Number of test variants produced when enabling data perturbation cannot be incrementally changed if the existing test assets are not removed before rerunning the test generation.
- Certain non-terminating looping in the model will cause test generation engine to hang.
- In certain cases, the test generation engine gives very poor time estimations on the remaining test generation time.

- Out of memory problems are not properly managed by Conformiq Computation Server and running completely out of memory most often causes server process to crash.
- If the Conformiq model has state chart with a transition that is triggered by an event "X", Conformiq test generation engine will not produce test cases for all the subtypes of "X" but for type "X" only.
- As described in Section Test Case Selection in Conformiq, Conformiq Computation Server selects from the test cases it has constructed a set that covers all the found test goals using a minimal cost test suite, where the cost of an individual test case is the number of messages in it squared. This ensures that the suite is reasonably small and compact but at the same time the individual test cases remain relatively short. In addition to this, Conformiq also prefers to cover all test goals as early as possible, i.e., after as few messages as possible. Due to the latter feature, the algorithm may select a test suite where a test X is coverage wise a proper subset of test Y; however, test X covers certain "checkpoints" with a better price than test Y. This, however, is not visible to the end user at all, which can lead to a situation where the end user feels that a certain test case is redundant.

Conformiq Modeler

- Occasionally, Conformiq Modeler will coalesce nearby transitions even when there is room for spreading them.
- In certain situations, it is difficult to move and reroute a transition as Conformiq Modeler "refuses to grab" the end of a transition.
- In certain situations, it is difficult to get rid of "transition string editing mode".
- In certain situations the transition arrows are not visible

Conformiq Eclipse Client

- Conformiq Eclipse Client automatically upgrades the format of the Conformiq projects when they are opened. The Conformiq projects, once opened, cannot be opened with an earlier versions of Conformiq.
- Highlighting of conditional branching structures (such as `if`, `for`, and `while` statements) in Model Browser in certain situations is confusing.
- Highlighting in Model Browser under certain platforms is not easily visible.
- RCP application on Linux does not remember last used workspace after software upgrade.
- The "small progress bar" on the lower right hand side corner of Eclipse user interface is in "circulating mode" instead of properly reflecting the overall progress.
- Clicking "Generate Tests" twice in Conformiq Eclipse Client causes two consecutive test generation runs while the action should be disabled while running the test generation. The same applies to "Load Model" action.
- Model browser does not show the content of the transition strings when using Enterprise Architect model import

A.5 Conformiq 4.3.1

Release date: January 19th, 2011

What's new or changed

- Model debugger has been enhanced by adding support for analyzing content of QML built-in container types. In addition, model debugger has been made more fault tolerant.
- Model importer has been enhanced by making it more fault tolerant.
- HP Quality Center integration has been enhanced when handling of non versioned

QC projects

- Client - server communication has been made more resilient towards communication errors.

A.6 Conformiq 4.3.0

Release date: December 31st, 2010

A.6.1 Model Debugger

Introducing model debugger that allows the user to analyze various issues in the model such as deadlock between multiple model components and to get a better understanding of the automatically designed and generated test cases.

The model debugger framework provides the capability to analyze in detail the situation in which the model level problem occurs (i.e. the state of the execution of the model) and it allows the means to analyze the execution trace that leads to the given problem via a single stepping model debugger. The model debugging in Conformiq Designer is organized so that the model defects (amongst test cases) are analyzed in a distinct new perspective called Conformiq Debugging. A distinct perspective helps us to keep the UI clear and understandable by providing only the views that are required for running the model debugger.

See Chapter Analyzing Model Defects for more information.

A.6.2 Support for Flexera Publisher Based Licenses

Introducing support for Flexera Publisher based licenses enabling the Conformiq Designer to operate with both Flexera based license server in addition to the Conformiq's proprietary simple web-based license server. End user with a Flexera license server can now deploy Conformiq technology without a need to deploy yet another license server at the same time.

See Chapter License Management in Conformiq for more information.

A.6.3 Internal Database Migration from PostgreSQL to SQLite

The server-side database system (PostgreSQL) internally used by Conformiq Designer has been removed from the release and replaced with an embedded client-side database system (SQLite). SQLite is designed to be embedded into the software, and it keeps the database in a single file, or, if required, in memory.

The Conformiq projects created with Conformiq Qtronic 2.1 or older cannot be opened with Conformiq 4.3 or newer. However, the PostgreSQL database system is still part of Conformiq 4.2 for the sake of migrating Conformiq projects to the new database system. Therefore, in order to migrate a project created with Conformiq Qtronic 2.1 or older, install Conformiq 4.2 on your machine and open the old Conformiq project. The Conformiq 4.2 release will upgrade the project format so that it can then be opened in Conformiq 4.3.

See Section Notes on Migrating to 4.3 Release for more information.

A.6.4 Support for Temporarily Increasing the Search Depth

Introducing construct to the QML modeling language that is used to increase the search exploration depth during automatic test generation (amount of lookahead) temporarily. The construct is useful when there are testing goals in the model that are not covered by the Conformiq Designer with the current search depth value where increasing the global search depth value has an unacceptable impact on the test generation time.

See Section Miscellaneous Functions for more information.

A.6.5 Support for Including State Charts

Introducing support for splitting the implementation of a single state chart into multiple files via the new QML modeling construct. The main benefit of this feature is that an engineering team can distribute the work of modeling a state chart over multiple engineers who can work with their individual files, without being concerned that there may be conflicts introduced when they commit their work to a version control system as multiple team members are contributing to a single state chart.

See Section Including State Charts for more information.

A.6.6 Experimental Support for Model Regions

Introducing an experimental support for model regions that are used to identify special parts of the behavior, for example, related to system configuration for which Conformiq Designer aims to design functional tests for not just one but all feasible system configuration parameter settings.

Note that the feature is considered to be experimental and subject to change in the future.

See Section Model Regions for more information.

A.7 Conformiq 4.2.2

Release date: November 29th, 2010

What's new or changed

- Provides possibility to access backend scripters from external "scripter warehouse" (see How to Use Scripters from Scripter Warehouse for more information)
  - Users can access scripters via Conformiq Designer Eclipse client and download them
  - Scripters are versioned providing the user with possibility to download updates when available
- An option for automatically registering Conformiq server binaries to firewall exception rules has been added to Conformiq installer on Windows. This option is enabled by default but user can change this during the installation time.
- Algorithmic optimizations and enhancements
  - Handling of preferred record field values have been significantly optimized

    - Handling of optional record field values have been significantly optimized
- Several usability enhancements has been made to Conformiq Modeler.
- Several issues with model importer have been fixed.
- Parallel test generation algorithm has been made more fault tolerant
- Problem with libXi.so dangling link in Linux installer has been fixed
- Enterprise Architect model importer has been extended to support stereotyped classes for describing QML record types. See Records for more information.

A.8 Conformiq 4.2.1

Release date: July 9th, 2010

What's new or changed

- Several algorithmic optimizations and enhancements which allow users to generate tests faster
    - Enhanced test generation algorithm to aggressively parallelize the test generation.
    - A number of core test generation algorithm optimizations.
- A support for recommending a memory configuration based on the hardware configuration for a couple of different use cases has been added to Conformiq installers. The installer will also deploy the configuration at install time if user wishes so.
- Java / CQA editing mode has been added to Conformiq Eclipse RCP application
- The parser of QML compiler has been optimized making the process of importing model files faster.

A.9 Conformiq 4.2.0

Release date: May 20th, 2010

Test Generation

Combinatorial Test Data Generation

Introduce a support for explicit test data generation where the QML language is extended with constructs that allow user to mark certain model regions from which Conformiq Designer strives to generate more combinations thus more tests. This feature helps the user to get rid of a problem where there the user has a reason to believe that a certain parts of the system are broken and would need to be tested with multiple different message combinations. See Section Modeling Combinatorial Test Data for details.

QML Record Preferred Values

Introduce a feature that provides the user the means of specifying preferred values for fields of messages received as external input. These preferred values are "hints" to the engine which then attempts to use the given preferred value unless stated otherwise in the model. See Section Preferred Values of Record Fields for details.

Test Generation Engine Optimizations

The performance of the core test generation algorithm has been improved by carefully pre-planning the work that parallel Conformiq computation services carry out in order to maximize the efficiency of the calculation by eliminating redundant work.

Modeling

TTCN-3 Type Import

Support for reusing existing type definitions written in TTCN-3 test framework in QML models. With this feature, the user can import existing type definitions

written in TTCN-3 and reuse those definitions directly in the QML models just like those definitions would be defined in QML. See Section Importing TTCN-3 Type Definitions Into Conformiq for details.

IBM Rational Software Architect RealTime Edition Model Import

Introduce a support for importing class and state chart diagrams from IBM Rational Software Architect RealTime Edition (RSARTE) with QML as the action language. The logical structure of the model is imported to Conformiq in UML2/XMI format which can be exported from RSARTE. In order to import the physical structure of the model for representing the diagram structure in the model browser, the native EMX files needs to be part of the imported model which RSARTE model importer use to import the physical structure of the model. See Section Rational Software Architect for details.

Extended Enterprise Architect Model Import

Sparx Systems Enterprise Architect model importer is extended with support for class diagrams. Also the physical model structure is imported and shown in the model browser. See Section Enterprise Architect for details.

Usability

Conformiq Project Wizard

Introduce an extended Conformiq project wizard for generating a skeleton model files (including a dummy state machine, main entry point, and empty system block) in addition to empty project with a default test design configuration. See Section How to Work with Conformiq Projects for details.

Detection of Conflicting Requires

Introduce a support for detecting and reporting require statements (i.e. syntactic lines) that possibly introduce conflicts in the model helping user in analyzing why Conformiq Designer does not reach certain parts of the model. See Section Assertion Like Functions for details.

Other Infrastructure

Requirement and Test Management Tool Integrations

Introduce tool functionality where Conformiq is able to import requirement catalogs from 3rd party requirement management tools. These requirements are imported just before or during the model import and once the model has been imported i.e. it has been parsed and checked against type errors and similar, the requirement annotations from the model are cross checked against the requirement catalog. If there is a mismatch, a report is produced and presented to the user. With test management integrations Conformiq is able to publish automatically generated test cases to a given test management tool after the test generation. See Chapter Test and Requirement Management Tool Integrations for details.

The release will introduce integrations with the following 3rd party requirement and test management tools

- IBM RequisitePro (requirement management tool) version 7.1 (see Section IBM Rational RequisitePro Integration for details)
- HP QualityCenter (requirement and test management tool) version 9 and 10 (see Section HP Quality Center Integration for details)
- IBM DOORS (requirement management tool) version 9.2 (see Section IBM Rational DOORS Integration for details)

Internal Database Migration from PostgreSQL to SQLite

The server-side database system (PostgreSQL) is replaced with an embedded client-side database system (SQLite). SQLite is designed to be embedded into the software, and it keeps the database in single file, or, if required, even in memory.

This feature will obsolete Save Conformiq Project function from the user interface which is the only visible change that this feature introduces to the user; however behind the scenes this migration makes the handling of databases more robust and marginally faster. The main benefit of this migration is that it will make Conformiq more stable.

The Conformiq projects, once opened, cannot be opened with an earlier version of Conformiq Qtronic.

A.10 Qtronic 2.1.2

Release date: February 1st, 2010

What's new or changed

- Startup of Qtronic Computation Server has been enhanced by making the startup sequence more robust and reliable.
- OSI Methodology Support has been enhanced so that it reuses existing test assets.
- IBM/Telelogic Rhapsody model importer has been enhanced to support initial attribute values amongst others.
- Sparx Systems Enterprise Architect model importer has been extended to support timer triggers in state charts.
- Several limitations of nullable types in Qtronic Modeling Language have been eliminated.
- Initialization of internal database at installation phase has been enhanced.
- TTCN-3 scripter backend has been extended to support arbitrary test case names.
- Stability of Qtronic has been increased in overall.
- Highlighting the execution paths leading to model defects in built-in Model Browser has been fixed.

A.11 Qtronic 2.1.1

Release date: September 21st, 2009

What's new or changed

- Internal project storage format has been enhanced to make test case handling faster and embedded PostgreSQL database system has been upgraded. Note that the project files saved with Qtronic 2.1.1 are not backward compatible with Qtronic 2.1.0.
- Selection for whether model profiling data is gathered has been added to project properties. The model profiler is disabled by default.
- Test suite selection uses approximate algorithm if search for the most optimal test suite takes otherwise too long.
- Multi core detection now supports Intel® Hyper-Threading Technology and some other multi-CPU configurations better in Windows platforms.
- Qtronic now works also in Windows XP without Service Pack 3. Conformiq recommends installing SP3 to take advantage of full multi core support.
- Problems with Eclipse Java editor when editing QML model files have been fixed.
- Stability of Qtronic has been increased.
- Memory usage of Qtronic has been reduced.

A.12 Qtronic 2.1.0

Release date: July 13th, 2009

What's new or changed

Multi Core Support

Introducing the capability to employ multiple CPU cores on a single laptop/desktop to speed up test generation accordingly. This feature is enabled by default and does not require any user actions.

High Performance Computation (HPC) Support

Introducing the capability to distribute test generation on multiple PCs, for example in a cluster-type hardware configuration.

Model Browser

Provides a read only presentation of the graphical model parts in the tool. Enables browsing of the model in the user interface and a visual mapping of the generated test cases and encountered model defects back to the model. See Section Model Browser for more information about the Model Browser.

Model Profiler

Provides the capability to record where Qtronic spends most of the time while generating tests from a particular model and pinpointing the problematic constructs in the model. See Section Model Profiler for more information about the Model Profiler.

OSI Methodology Support

Provides support for generating test suites conforming to the OSI methodology for organizing test cases as laid out in ISO 9646-1 standard, and for dependency-based test execution. Helps to pinpoint tested requirements more accurately, and provides automatic and consistent naming of generated test cases. See Section OSI Methodology Support for more information about this feature.

IBM/Telelogic Rhapsody Model Import

Introducing a support for importing class and statechart diagrams from IBM/Telelogic Rhapsody with QML as the action language. See Section Rhapsody System Designer for more information.

Qtronic RCP Application

In addition to installing Qtronic Eclipse Client as an Eclipse plug-in, the QEC user interface can be installed as an RCP application, standalone software which does not require an existing Eclipse installation.

Support for Entry and Exit Actions to Conformiq Modeler

Enhances and extends QML modeling language by adding support for entry and exit action to states. Entry action code is always executed when a state is entered, and exit action code is executed when a state is left. See Section Entry and Exit Actions for more information.

User Interface Enhancements

(1) Introducing support for showing external ports as separate lifelines in the Test Case view, which helps to understand and visualize the generated test cases.

(2) Introducing support for "file hyperlinks" for scripter backends so that the user can open and analyze the actual exported test cases simply by clicking the hyperlinks in the console output window.

Enhanced Demo Package

Introducing more comprehensive self explanatory example projects and enhancing the existing ones.

Compositional End-to-End Testing Feature Additions

Introducing additional features for verifying that the two end-to-end models (such as a client and a server model) interoperate so that the two components should not trigger error management behavior in their counterparts, because that would mean that one of the components is non-conformant.

On-demand Qtronic Computation Server Startup

Qtronic user interface can be configured to automatically start the Qtronic Computation Server if it is not already running to make working with Qtronic as seamless as possible.

Extended Selection of Scripting Backends

(1) Introducing HP Quality Center (a test management tool) scripting backend for publishing Qtronic generated test cases in QC.

(2) Introducing Perl scripting backend for rendering directly executable test cases in Perl.

(3) TTCN scripting backend has been extended with numerous new configuration options.

Automatic Software Update Check

Qtronic 2.1 checks automatically for the availability of updates against the Conformiq website, when external HTTP connectivity is available.

A.13 Qtronic 2.0.3

Release date: April 20th, 2009

What's new or changed

- In order to accommodate the fact that functional requirements often contain a unique name or an identifier and a brief summary with possibly some rationale for the requirement, the `requirement` statement is extended so that a summary or a description can be given as an argument to requirement statement. See Section Requirements for more information.
- In a case where the model contains an internal computation error such as a division by zero, Qtronic Eclipse Client user interface will now also present dynamic stack trace that leads to the error.
- Stability of the computation node has been increased.

A.14 Qtronic 2.0.2

Release date: January 16th, 2009

What's new or changed

- Management of client connections has been enhanced
- Management of the test asset database has been enhanced

- Stability and performance of the computation node has been increased

A.15 Qtronic 2.0.1

Release date: December 12th, 2008

What's new or changed

- Test cases for multiple Test Design Configurations are generated now in parallel which makes test generation faster by sharing test generation results between multiple Test Design Configurations more efficiently.
- Management of client connections is enhanced to increase redundancy of test generation results in case of connection problems.

A.16 Qtronic 2.0.0

Release date: November 17th, 2008

What's new or changed

- Complete redesign of Qtronic user space as Eclipse plugin.
- Separation of user interface and the test generation engine to distinct components that can be run on distinct workstations. Test generation engine can be run in Linux or in Windows.
- Incremental test case management and test case generation.
  - Generated test cases are stored after a test generation run to a persistent storage.
  - Previously generated test cases are used as input into consecutive incremental test generation runs providing faster test generation.
  - Possibility to name and rename generated test cases.

- Capability to browse and analyze generated test cases (and model defects) in the user interface including graphical I/O and execution trace; no need to export an HTML test plan.
- Only supports offline script generation. Support for online testing will be reintroduced in later 2.X releases.
- The generated tests are rendered in formats specified by script backends written in Java.
- Support for multiple design configurations or profiles. Each profile has their own coverage criteria and selection of script backends. There can be more than one script backend in a design configuration, while also generation of test cases is possible without having a script backends at all.
- Improved handling of coverage criteria
  - Finer grained control of coverage criteria as structural features can be individually selected.
  - Capability to also block coverage criteria in addition to marking coverage criteria as a target or "do not care".
  - Status of coverage criteria is updated in real time and visible at all times in the user interface.
- Simplified plugin API eases the task of developing new plugins.

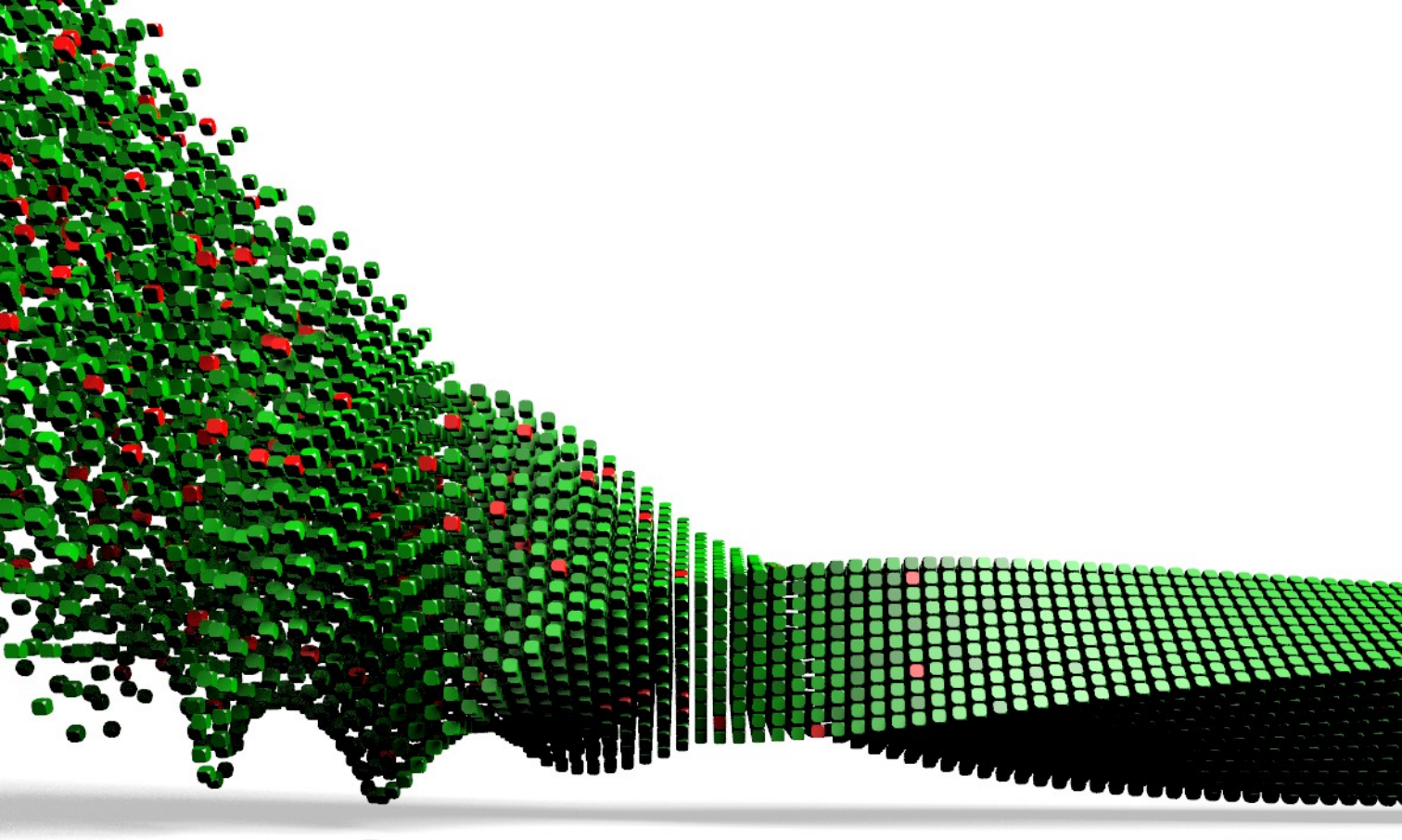
Benefits

In Qtronic 1.X the tool simply designs and generates the test cases, but the user cannot see the generated tests in the tool itself forcing the user to build a scripter plug-in before generating even a single test. In addition, Qtronic 1.X leaves it up to the user to manage and store the generated test cases. In Qtronic 2.0, on the other hand, the generated tests are stored in persistence data storage and the generated tests are visible in the Qtronic 2.0 user interface allowing the user to make detailed analysis of the generated tests. Only after the

tests have been generated, the user has the possibility to export tests in the expected format using a set of scripter plug-ins.

In addition to test case management, the user interface of Qtronic 2.0 has been redesigned and re-implemented from scratch making the look and feel more professional and enhancing the user experience significantly. Also, the user interface and computation engine component has been separated allowing the user to run Qtronic 2.0 on a low end computer without significantly sacrificing the performance of the computer: the heavy computation can be carried out in a high end sever computer with fast CPU and a great amount of memory. However, this does not prevent the user from running the user interface and computation engine on the very same computer, if this is required.

One additional feature in Qtronic 2.0 is the test generation profiles called design configurations. The design configurations allow the user to create different profiles with different coverage settings and scripter plug-ins for different use cases. For example, users can define a design configuration for verifying the basic requirements and another for generating test cases that stresses the boundary values of integral comparisons in the model.



B Plugin API Reference Manual

com.conformiq.qtronic2.*QMLValue* Interface

Description

Interface for QMLValues.

Interface Overview

```
interface QMLValue {
        public void accept(QMLValueVisitor);
        public QMLType getType();
}
```

Member Details

void accept(*QMLValueVisitor* visitor) **method**

Accept QML value visitor.

***QMLType* getType()** **method**

Get the type of this value.

com.conformiq.qtronic2.*QMLTypeVisitor* Interface

Description

Visitor interface for visiting QMLTypes.

Interface Overview

```
interface QMLTypeVisitor {
        public void visit(QMLArrayType);
        public void visit(QMLBooleanType);
        public void visit(QMLNumberType);
        public void visit(QMLRecordType);
        public void visit(QMLStringType);
        public void visit(QMLOptionalType);
}
```

Member Details

void visit(*QMLArrayType* a) **method**

Visit a QML array.

void visit(*QMLBooleanType* b) **method**

Visit a QML boolean.

void visit(*QMLNumberType* n) **method**

Visit a QML number.

void visit(*QMLRecordType* r) **method**

Visit a QML record.

void visit(*QMLStringType* s) **method**

Visit a QML string.

void visit(*QMLOptionalType* p) **method**

Visit a QML optional type.

com.conformiq.qtronic2.*Checkpoint* Interface

Description

Interface for checkpoints

Interface Overview

```
interface Checkpoint {
        public java.lang.String getName();
        public int getType();
}
```

Member Details

java.lang.String getName() **method**

Return name of this checkpoint

int getType() **method**

Return type of this checkpoint

com.conformiq.qtronic2.*QMLRecordType* Interface

Description

Interface for *QMLRecordType*.

Interface Overview

```
interface QMLRecordType extends QMLType {
        public QMLRecordTypeField getField(int);
        public QMLRecordType getInnerType(int);
        public int getNumberOfFields();
        public int getNumberOfInnerRecords();
}
```

Member Details

***QMLRecordTypeField* getField(int idx)** **method**

Get record fields (type, field name pairs).

***QMLRecordType* getInnerType(int idx)** **method**

Inner types.

int getNumberOfFields() **method**

Number of record fields.

int getNumberOfInnerRecords() **method**

Number of inner records.

com.conformiq.qtronic2.*QMLNumber* Interface

Description

Interface for *QMLNumber*.

Interface Overview

```
interface QMLNumber extends QMLValue {
        public BigInteger getBigInteger();
        public BigInteger getDenominator();
        public double getDouble();
        public long getInteger();
        public BigInteger getNumerator();
        public boolean isBigInteger();
        public boolean isDouble();
        public boolean isInteger();
        public void setBigInteger(BigInteger);
        public void setDouble(double);
        public void setInteger(long);
        public void setRational(BigInteger, BigInteger);
}
```

Member Details

BigInteger getBigInteger() **method**

BigInteger getDenominator() **method**

double getDouble() **method**

Get the double value.

long getInteger() **method**

Get the integer value.

BigInteger getNumerator() **method**

boolean isBigInteger() **method**

boolean isDouble() **method**

Is the number a double?

boolean isInteger()	**method**

Is the number an integer?

void setBigInteger(BigInteger value)	**method**

void setDouble(double value)	**method**

void setInteger(long value)	**method**

void setRational(BigInteger nominator, BigInteger denominator)	**method**

com.conformiq.qtronic2.*Plugin* Class

Description

This is a high-level base class for all kind of plugins used by Conformiq Designer.

Class Overview

```
class Plugin {
       public boolean setConfigurationOption(java.lang.String,
java.lang.String);
       public boolean setMetaData(MetaDataDictionary);
       public void setNotificationSink(NotificationSink);
}
```

Member Details

boolean setConfigurationOption(java.lang.String property, java.lang.String value)	**method**

Set value of configuration option. *Plugin* can use this method to get access to two kinds of

configuration options:

1) Configuration options that are set in the Conformiq Designer user interface (f.ex. used testing heuristics and model level coverage options). 2) User defined configuration options that are based on the XML document 'Configuration.xml' inside the JAR file of the plugin.

In the case there is a subtree in the user defined configuration option, property contains tree in dot separated format (e.g. "dir1.dir2.item"). Return value indicates if this is acceptable value for this property or not. E.g. if property is TCP port number and user enters non-number, *Plugin* should return false.

boolean setMetaData(*MetaDataDictionary* dict) **method**

Set metadata dictionary. Return true if the plugin as capable of receiving the pointer to the metadata dictionary, otherwise false. In practice, always return true. There is a default implementation that returns true.

void setNotificationSink(*NotificationSink* sink) **method**

Called after construction to set notification callback object pointer.

com.conformiq.qtronic2.*QMLOptional* Interface

Description

Interface for *QMLOptional*.

Interface Overview

```
interface QMLOptional extends QMLValue {
        public QMLValue getValue();
        public boolean isPresent();
        public void setValue(QMLValue);
}
```

Member Details

***QMLValue* getValue()** **method**

Get the value.

boolean isPresent() **method**

Is the value present. Otherwise it is omitted.

void setValue(*QMLValue* value) **method**

com.conformiq.qtronic2.*TimeStamp* Class

Description

Timestamp structure.

Class Overview

```
class TimeStamp {
        public int nanoseconds;
        public int seconds;
}
```

Member Details

int nanoseconds **variable**

int seconds **variable**

com.conformiq.qtronic2.Checkpoint.*CheckpointStatus* Class

Description

Checkpoint log item types.

Class Overview

```
class CheckpointStatus {
        public final int COVERED;
        public final int MAYBE_COVERED;
        public final int UNCOVERED;
        public final int UNREACHABLE;
        public final int UNREACHABLE_HERE;
}
```

Member Details

final int COVERED **static variable**

Checkpoint has been covered during this run.

final int MAYBE_COVERED **static variable**

Checkpoint may have been covered during this run.

final int UNCOVERED **static variable**

Checkpoint not covered in this run yet.

final int UNREACHABLE **static variable**

Checkpoint statically unreachable.

final int UNREACHABLE_HERE **static variable**

Checkpoint unreachable for the rest of the run.

com.conformiq.qtronic2.*QMLArrayType* Interface

Description

Interface for *QMLArrayType*.

Interface Overview

```
interface QMLArrayType extends QMLType {
        public QMLType getType();
}
```

Member Details

***QMLType* getType()** **method**

Get type of array's members.

com.conformiq.qtronic2.*QMLUnion* Interface

Description

Interface for *QMLUnion*.

Interface Overview

```
interface QMLUnion extends QMLRecord {
        public java.lang.String chosenField();
        public boolean isChosen(java.lang.String);
}
```

Member Details

java.lang.String chosenField() **method**

Returns the name of the chosen field or null if no field is chosen.

boolean isChosen(java.lang.String field) **method**

Returns true if the given field is currently chose (active).

com.conformiq.qtronic2.*QMLRecord* Interface

Description

Interface for *QMLRecord*.

Interface Overview

```
interface QMLRecord extends QMLValue {
        public QMLRecordField getField(int);
        public QMLRecordField getField(java.lang.String);
        public java.lang.String getName();
        public int getNumberOfFields();
        public void setField(java.lang.String, QMLValue);
}
```

Member Details

QMLRecordField getField(int idx) **method**

Get a field at the given index. It is an error to index out of bounds.

QMLRecordField getField(java.lang.String field) **method**

Get value of the given field by field name.

java.lang.String getName() **method**

Get name of this record's type.

int getNumberOfFields() **method**

Get the number of fields in this record.

void setField(java.lang.String field, _QMLValue_ value) **method**

Set value of the given field.

field value

com.conformiq.qtronic2.*QMLBoolean* Interface

Description

Interface for *QMLBoolean*.

Interface Overview

```
interface QMLBoolean extends QMLValue {
        public boolean getValue();
        public void setValue(boolean);
}
```

Member Details

boolean getValue() **method**

Get the value of this boolean.

void setValue(boolean value) **method**

com.conformiq.qtronic2.*QMLRecordTypeField* Interface

Description

Interface for QMLRecordTypeFields.

Interface Overview

```
interface QMLRecordTypeField {
        public java.lang.String getFieldName();
        public QMLType getType();
        public java.lang.String getTypeName();
}
```

Member Details

java.lang.String getFieldName() **method**

Get field name.

***QMLType* getType()** **method**

Get type of the field.

java.lang.String getTypeName() **method**

Get type name of the field.

com.conformiq.qtronic2.*MetaDataDictionary* Interface

Description

This is a dictionary for metadata of a model.

Interface Overview

```
interface MetaDataDictionary {
        public QMLValue get(java.lang.String);
        public QMLBooleanType getBooleanType();
        public QMLNumberType getByteType();
        public QMLNumberType getCharType();
        public QMLNumberType getDoubleType();
        public QMLNumberType getFloatType();
        public QMLNumberType getIntType();
        public QMLNumberType getLongType();
        public java.lang.String getNextKey(java.lang.String);
        public QMLNumberType getShortType();
        public QMLStringType getStringType();
        public QMLRecordType getType(java.lang.String);
        public java.util.Vector< QMLRecordType > getTypes();
}
```

Member Details

***QMLValue* get(java.lang.String key)** **method**

Return data associated with key. Returns null pointer if no data associated.

***QMLBooleanType* getBooleanType()** **method**

Access primitive types.

***QMLNumberType* getByteType()** **method**

***QMLNumberType* getCharType()** **method**

***QMLNumberType* getDoubleType()** **method**

***QMLNumberType* getFloatType()** **method**

QMLNumberType **getIntType()**	**method**

QMLNumberType **getLongType()**	**method**

java.lang.String getNextKey(java.lang.String key)	**method**

Return the lexiographically next key in the metadata dictionary. *key* does not need to be a valid entry in the dictionary. Returns the lexiographically next key that has associated data in the dictionary. Returns never *key* itself, but always a lexiographically later key. Returns null pointer if there are no keys after *key* in the lexiographic ordering. The lexiographic ordering is unspecified for keys containing other than ASCII octets.

QMLNumberType **getShortType()**	**method**

QMLStringType **getStringType()**	**method**

QMLRecordType **getType(java.lang.String name)**	**method**

Access type by its name.

java.util.Vector< *QMLRecordType* **> getTypes()**	**method**

Get all the QML record types defined in the model.

com.conformiq.qtronic2.*QMLType* Interface

Description

Interface for QMLTypes.

Interface Overview

```
interface QMLType {
        public void accept(QMLTypeVisitor);
        public java.lang.String getTypeName();
}
```

Member Details

void accept(*QMLTypeVisitor* visitor) **method**

Accept QML type visitor.

java.lang.String getTypeName() **method**

Name of the type.

com.conformiq.qtronic2.Checkpoint.*CheckpointType* Class

Description

Type of checkpoint.

Class Overview

```
class CheckpointType {
        public final int REQUIREMENT;
        public final int USUAL_CHECKPOINT;
}
```

Member Details

final int REQUIREMENT **static variable**

Requirement

final int USUAL_CHECKPOINT **static variable**

Normal checkpoint

com.conformiq.qtronic2.*QMLStringType* Interface

Description

Interface for *QMLStringType*.

Interface Overview

```
interface QMLStringType extends QMLType {
}
```

Member Details

com.conformiq.qtronic2.*QMLRecordField* Interface

Description

A field of a QML record.

Interface Overview

```
interface QMLRecordField {
        public QMLRecordTypeField getFieldType();
        public java.lang.String getName();
        public QMLValue getValue();
        public void setValue(QMLValue);
}
```

Member Details

QMLRecordTypeField **getFieldType()** **method**

Get field definition of this field.

java.lang.String getName()	**method**

Record field has a field name.

***QMLValue* getValue()**	**method**

Record field has a value.

void setValue(*QMLValue* value)	**method**

com.conformiq.qtronic2.*QMLUnionType* Interface

Description

Interface for *QMLUnionType*.

Interface Overview

```
interface QMLUnionType extends QMLRecordType {
}
```

Member Details

com.conformiq.qtronic2.*QMLBooleanType* Interface

Description

Interface for *QMLBooleanType*.

Interface Overview

```
interface QMLBooleanType extends QMLType {
}
```

Member Details

com.conformiq.qtronic2.*QMLValueVisitor* Interface

Description

Visitor interface for visiting QMLValues.

Interface Overview

```
interface QMLValueVisitor {
        public void visit(QMLArray);
        public void visit(QMLBoolean);
        public void visit(QMLNumber);
        public void visit(QMLRecord);
        public void visit(QMLString);
        public void visit(QMLOptional);
}
```

Member Details

void visit(*QMLArray* a) **method**

Visit a QML array.

void visit(*QMLBoolean* b) **method**

Visit a QML boolean.

void visit(*QMLNumber* n) **method**

Visit a QML number.

void visit(*QMLRecord* r) **method**

Visit a QML record.

void visit(*QMLString* s) **method**

Visit a QML string.

void visit(*QMLOptional* p) **method**

Visit a QML optional type.

com.conformiq.qtronic2.*QMLNumberType* Interface

Description

Interface for *QMLNumberType*.

Interface Overview

```
interface QMLNumberType extends QMLType {
        public boolean isByte();
        public boolean isDouble();
        public boolean isFloat();
        public boolean isInteger();
        public boolean isLong();
        public boolean isShort();
}
```

Member Details

boolean isByte() **method**

Is the number an integral?

boolean isDouble() **method**

boolean isFloat() **method**

Is the number a floating-point?

boolean isInteger() **method**

boolean isLong() **method**

boolean isShort() **method**

com.conformiq.qtronic2.*QMLOptionalType* Interface

Description

Interface for *QMLOptionalType*.

Interface Overview

```
interface QMLOptionalType extends QMLType {
        public QMLType getType();
}
```

Member Details

QMLType **getType**() **method**

Return type which has been made optional.

com.conformiq.qtronic2.*ScriptBackend* Class

Description

Abstract base class for script back-ends. Script back-ends render test scripts when Conformiq Designer works in the offline test script generation mode.

Class Overview

```
class ScriptBackend extends SynchronousPlugin {
        public abstract boolean beginCase(java.lang.String);
        public boolean beginCase(java.lang.String, java.lang.StringBuilder);
        public abstract boolean beginScript(java.lang.String);
        public void caseDescription(java.lang.String);
        public void caseID(int);
        public abstract void caseProbability(double);
        public abstract boolean checkpointInfo(Checkpoint, int, TimeStamp);
        public boolean checkpointInfo(Checkpoint, int, TimeStamp,
java.lang.String);
        public abstract boolean endCase();
        public abstract boolean endScript();
        public boolean narrativeInfo(java.lang.String);
        public boolean scenarioInfo(java.lang.String);
        public boolean sectionInfo(java.lang.String);
        public boolean testCaseDependency(java.lang.String, java.lang.String);
        public abstract boolean testStep(QMLRecord, java.lang.String,
java.lang.String, boolean, TimeStamp);
}
```

Member Details

abstract boolean beginCase(java.lang.String testcaseName) **abstract method**

Begin test case. This method is called zero or more times (usually more) after a call to *beginScript()*. The argument *testcaseName* is name of this testcase. Return true to indicate success and false to indicate an abnormal condition (test script generation will be aborted).

boolean beginCase(java.lang.String testcaseName, java.lang.StringBuilder stream) **method**

Begin test case. As above, except that *stream* is a string stream where the test case is to be written to. By default, throw UnsupportedOperationException to indicate that the given scripter does not support writing test cases to streams.

abstract boolean beginScript(java.lang.String testsuiteName) **abstract method**

Begin script is the first method called. The argument *testsuiteName* is name of this design configuration. If you return false from the method, script generation will not continue. Return true to indicate success.

void caseDescription(java.lang.String description) **method**

Test case description. The test case description is generated from the "narrative" fragments that are used to build a narrative of what happens in a test case from the system perspective

void caseID(int id) **method**

Set numeric "Test Case ID" defined by Conformiq Designer. This numeric ID can be used to maintain mapping from the given test case to the one in the Conformiq Designer user interface (in cases where you cannot derive the ID directly from the test case name).

abstract void caseProbability(double probability) **abstract method**

Set test case probability. This method should be called after *beginCase()* if test case probability is set.

abstract boolean checkpointInfo(*Checkpoint* checkpoint, int checkpointStatus, *TimeStamp* ts) **abstract method**

Render checkpoint information. This method is called zero or more times after a call to *beginCase()*. Return true to indicate success and false to indicate an abnormal condition (test script generation will be aborted).

The purpose of a call of this method is to render information about model-driven test

coverage in the generated test script. This should not affect test execution at all, so it is possible to generate valid and executable test scripts while ignoring all calls to this method. However, if you are interested in how the test scripts are mapped to model-driven coverage you can benefit from implementing this method properly.

checkpoint is the checkpoint whose status is reported at the particular point in the test script. *status* is the status, and *timestamp* is the timestamp at which the checkpoint status becomes known (usually the same as the previous message in the test script).

boolean checkpointInfo(*Checkpoint* checkpoint, int checkpointStatus, *TimeStamp* ts, java.lang.String thread) **method**

Render checkpoint information. As above, except that *thread* gives the name of the thread that covers the given checkpoint.

abstract boolean endCase() **abstract method**

End test case. Called after *beginCase()*. Return true to indicate success, false otherwise.

abstract boolean endScript() **abstract method**

End test script. Called after *beginScript()*. Return true to indicate success, false otherwise.

boolean narrativeInfo(java.lang.String name) **method**

Test case narrative. Narrative tags are used to produce a narrative of what happens in a test case from the system perspective.

boolean scenarioInfo(java.lang.String name) **method**

Test case scenario. As opposed to "test case narratives", the "scenario" fragments are not considered to be sentences and they do not necessarily form a sequential narrative but are more considered independent labels that together define the present scenario

boolean sectionInfo(java.lang.String section_name) method

Section marker. Used by the ISO 9696-1 option to designate the three different sections of a test case. The *section_name* argument can be either "Preamble", "Body", or "Postamble". This method is called whenever a section begins; the end of a section is implicit at the beginning of the next one, or at the end of the test case.

boolean testCaseDependency(java.lang.String prerequisite, java.lang.String dependent) method

Output dependency information. The test case with automatically generated name *prerequisite* is a prerequisite for test case *dependent*; in other words, test case *dependent* would likely fail during test execution if test case *prerequisite* fails. Note that it is possible that there are both forward and backward dependencies in the test suite (relative to the order in which test cases are published) even though the goal is to have only backward dependencies (later test cases depend on earlier ones).

abstract boolean testStep(*QMLRecord* datum, java.lang.String thread, java.lang.String port, boolean isFromTester, *TimeStamp* ts) abstract method

Render a test step. This method is called zero or more times (usually more) after a call to *beginCase()*. Return true to indicate success and false to indicate an abnormal condition (test script generation will be aborted).

The purpose of a call of this method is to render a single test step, i.e. a single test message either in the inbound or the outbound direction. The first argument *datum* is the datum that is either the sent or the expected message. The string *thread* is the name of thread in the model that is expected to send or receive the message. The string *port* is the inbound our outbound port through which the datum must be or should be transported. The *isFromTester* flag indicates the direction. This information is derived, because all the ports are unidirectional on this level. Finally, *timestamp* is the required or expected time when the message must be sent or received.

com.conformiq.qtronic2.*QMLArray*Interface

Description

Interface for *QMLArray*.

Interface Overview

```
interface QMLArray extends QMLValue {
        public int getNumberOfElements();
        public QMLValue getValue(int);
        public void insertAtEnd(QMLValue);
}
```

Member Details

int getNumberOfElements() **method**

Get the number of array elements.

***QMLValue* getValue(int idx)** **method**

Get the value at the given index. It is an error to index out of array bounds.

void insertAtEnd(*QMLValue* value) **method**

com.conformiq.qtronic2.*SynchronousPlugin* Class

Description

Scripting and Logging backends work in synchronous manner, and this is an super interface for both of those.

Class Overview

```
class SynchronousPlugin extends Plugin {
       public abstract boolean internalCommunicationsInfo(QMLRecord,
java.lang.String, java.lang.String, java.lang.String, TimeStamp);
       public abstract boolean trace(java.lang.String, TimeStamp);
}
```

Member Details

abstract boolean internalCommunicationsInfo(*QMLRecord* datum, java.lang.String sender, java.lang.String receiver, java.lang.String port, *TimeStamp* time) abstract method

Render an internal message take-over, ie. an internal communication step. Return true to indicate success and false to indicate an abnormal condition (test script generation will be aborted).

The purpose of a call of this method is to render a single internal communications step, i.e. a single message take-over between internal threads in the model. The first argument *datum* is the datum that is sent from thread *sender* and it is received by thread *receiver*. The string *port* is the internal port through which the datum is transported. Finally, *timestamp* is the time when the message is sent and received.

abstract boolean trace(java.lang.String message, *TimeStamp* time) abstract method

QML language has a predefined *trace()* function for displaying messages in the log window of Conformiq Designer while testing. Conformiq Designer invokes Trace() function of each connected script and logger plugin once this expression is executed by the Conformiq Designer engine. *message* is the outputted trace message and *time* is the timestamp at which the *trace()* function is executed by Conformiq Designer.

com.conformiq.qtronic2.*QMLString* Interface

Description

Interface for *QMLString*.

Interface Overview

```
interface QMLString extends QMLValue {
        public java.lang.String getValue();
        public void setValue(java.lang.String);
}
```

Member Details

java.lang.String getValue() **method**

Get the value of this string.

void setValue(java.lang.String value) **method**

com.conformiq.qtronic2.*NotificationSink* Interface

Description

Interface for plugins' callback interface. An object that implements the *Plugin* interface communicates with an object that implements the *NotificationSink* interface. In the basic setting, Conformiq's testing tool implements *NotificationSink*, and receives notifications from plugins.

Interface Overview

```
interface NotificationSink {
        public void notify(java.lang.String, java.lang.String);
}
```

Member Details

void notify(java.lang.String notificationClass, java.lang.String message) **method**

Send extra information about Plugin's state. *notificationClass* describes the type of the notification; valid values are "info", "warning" and "error". *message* is the actual information piece.